TIDAL AND CURRENT PREDICTION FOR THE AMAZON'S NORTH CHANNEL USING A HYDRODYNAMICAL-NUMERICAL MODEL

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FOR THE AMAZON'S NORTH CHANNEL
USING A HYDRODYNAMICAL-NUMERICAL MODEL

by

Luiz Antonio de Carvalho Ferraz

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cm	centimeter
cm^2	square centimeter
cm^3	cubic centimeter
cm/sec	centimeter per second
cm^2/sec	cubic centimeter per second
d	total difference
F	friction force
f	Coriolis parameter
g	acceleration of gravity
H	total depth ($H = h + \zeta$)
h	depth of water at mean water level
HM	harmonic method of prediction of tides
HN	hydrodynamical-numerical prediction model
hr	hour
HTU,HTV	depth at U- and V- grid points
HT	high tide
HTZ	symbolic depth at Z-grid points
K	coefficient of horizontal kinematic eddy viscosity
km	kilometer
km^2	square kilometer
L	characteristic length
ℓ	length of the mesh
LT	low tide
M,N or m,n	grid coordinates

m	meter
m^2	square meter
m^3	cubic meter
m^3/sec	cubic meter per second
n mile	nautical mile
NE, ME	grid delimeters
NEH, MEH	near border grid coordinates (NEH = NE - 1, MEH = ME - 1)
p	hydrostatic pressure
R	bottom roughness coefficient
r	coefficient of bottom friction
t	time
u, v	velocity components
U, V	mean u and v components
$\vec{V}$	total velocity vector
$W_{(x)}$, $W_{(y)}$	wind speed components
X,Y or x,y	space coordinates
Z, U, V	grid points
α	smoothing parameter
β	1 - α
δ	partial difference
γ	specific weight
λ	drag coefficient
ζ	water level anomaly
ρ	density of the fluid
τ	wind stress
τ^b	bottom stress

$\vec{\omega}$	earth angular velocity
Δ	difference, also, in figures, represents tide station
Δt	half-time step
∇^2	$\frac{\delta^2}{\delta x^2} + \frac{\delta^2}{\delta y^2}$ (Laplacian)

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I. INTRODUCTION

A. REVIEW

Pressure gradients are the dominant mechanisms in rivers, narrow estuaries and some lakes which are opposed by friction [21]. In large scale circulation the opposing forces are combinations of friction and the Coriolis force or the latter alone.

Hydraulic models have been used for many years to reproduce the physical characteristics of rivers and have proven to be reliable, but space and operating problems make them a relatively expensive tool of investigation. The appearance of high speed computers made possible the numerical solution of the differential equations used to describe flow. A physical model can be transformed into a program which may be modified easily to simulate different conditions and may be stored for future utilization and alteration, thus allowing solutions to be obtained rapidly and at a reasonable cost.

The hydrodynamical-numerical method developed by W. Hansen makes it possible to determine the motion in oceanic areas, in adjacent and marginal seas, in shelf areas as well as in estuaries and rivers [15, 18]. In many cases the method has been applied successfully to the quantitative reproduction of tides and storm surges. The numerical treatment of the hydrodynamical equations requires the bathymetry, boundary geometry, and meteorological and density structure to be considered.

This model has been applied to rivers such as the Eider, the Ems and the Elbe, in Germany [9, 17, 18]. The Eider is a tidal river in northern Germany with very irregular cross-sections and a remarkably irregular depth distribution. Application of the HN-model with a very fine mesh, to approximate the cross-sections by a number of parallel canals of differing width and depth, produced good results with a maximum deviation of 30 cm between computed and observed tides, which is less than 10% of the tidal range. Later computations with improvements in the longitudinal direction from grid point to grid point made it possible to reduce the deviations between the computed and observed values to below 3.5 cm, which was about 1% of the tidal range [17]. Similar applications of the HN-model were made to the Ems and the Elbe, and the results were in all cases of the same order of magnitude. For the Elbe the differences were smaller than 2 cm [9, 17].

In this study the hydrodynamical-numerical prediction model of Hansen is applied to the Amazon's North Channel and the results are compared to field observations.

B. OBJECTIVE

The objective of this thesis is to predict by means of the Hansen hydrodynamical-numerical model tides and currents which exist in the North Channel of the Amazon River during an intermediate river stage and to compare the numerical results with available field measurements. The computed tides are compared to prediction by harmonic method at three tide stations along the channel and the currents are compared to field observations at selected locations.

A medium size square mesh grid is used to represent the North Channel's configuration and bottom topography. The numerical results will provide means of evaluating this representation in terms of grid size as well as of the merits and limitations of the HN-model.

II. DESCRIPTION OF THE NORTH CHANNEL OF THE AMAZON RIVER

A. GENERAL

The Amazon River is located in South America, where it begins its eastward flow from a chain of glacier-fed lakes in the Andes Mountains in central Peru. It emerges from the eastern foothills of the Andes, sweeps through the world's largest tropical rain forest, and discharges into the Atlantic Ocean on the northern coast of Brazil. En route to the Atlantic the river drains about 7×10^6 km^2 of land, receiving the flow of over 200 tributaries.

The Amazon is the world's largest river in terms of drainage area and discharge. Its discharge is subjected to seasonal fluctuations. Two periods are generally considered: (1) that from April to June, the rain season or the high water stage; and (2) that from October to December, the season of low precipitation or low water stage.

Investigations and measurements made by the University of Brazil, the Brazilian Navy, and the U.S. Geological Survey in 1963 and 1964 produced some astonishing numbers for the flow of the river. The flow at Obidos (some 850 km from the mouth) during the high stage measured about 216,000 m^3/sec, during low stage about 72,500 m^3/sec, and during an intermediate stage, 164,520 m^3/sec. The average flow, estimated for the discharge into the Atlantic Ocean, was slightly over 175,000 m^3/sec [2, 19, 20].

The river is generally deep, and in more than ten locations depths greater than 100 m have been found. The width of the

channel ranges from about 2 km at its narrowest up to about 10 km in some places, with long sections having intermediate values [2, 19].

Gibbs [12] and Diegues [3] have shown that the Amazon waters spread over the Atlantic Ocean in a variable layer, 10 to 20 m thick, under which the oceanic water progresses towards the shore. Gibbs [12] showed that during the high stage of the river a vertical stratification ranges out over the continental shelf, to distances of 80 to 230 km from the mouth, and during the low stage it ranges out to 60 to 185 km. However, all vertical isohalines indicative of turbulent mixing are limited to the mouth of the river, and there is never penetration of salt water into the river as occurs in some types of estuaries [12, 13].

B. CHARACTERISTICS OF THE TIDES AND CURRENTS IN THE AMAZON RIVER

The Amazon River seems to have the longest river tide-zone in the world [1]. Tides are observed up to the vicinity of Santarem harbor, some 800 km from the river's mouth, but during extremely low flows tidal effects have reached upstream to Obidos. The tides are of semidiurnal type with a maximum range of about 5 m. Field measurements indicate that the tidal variation decreases upstream.

Tides and river flow combine to produce strong currents in many sites upstream. The North Channel (Fig. 1) has a single main entrance from the sea, but numerous small tributaries and channels also offer secondary connections to the ocean.

In many of these channels a tidal bore is a peculiar characteristic.

Franco [8] characterizes the current in the North Channel in the vicinity of Macapa as "alternating-axial" (rectilinear or reversing), that is, the alternating current component superimposed on the main downstream river flow is maximum upstream during the high water, maximum downstream during the low water and it is zero when the tide is at the mean water level. There is a relatively strong permanent current downstream due to the enormous discharge of the river.

C. THE AREA OF STUDY

The Amazon discharges into the Atlantic in two branches. The present study is limited to a region of the upper branch which constitutes the North Channel, extending some 147 km from the mouth. This channel is the navigable waterway from the river's mouth to the ports of Macapa and Santana in the Brazilian Federal Territory of Amapa (Fig. 1).

The Port of Santana is utilized mainly by the large vessels that carry manganese ore extracted from the mines of Serra do Navio, inland of Amapa. Navigation in the North Channel is somewhat difficult due to natural conditions in the river, such as enormous floating trees, sometimes attached to floating grass "islands," pulled down from the adjacent margins by erosion, strong currents, and a large tidal variation. The harbor at Santana is of the floating type to compensate for the large tidal range and for the seasonal fluctuations of the river level. The port of Macapa consists mainly of a wharf where

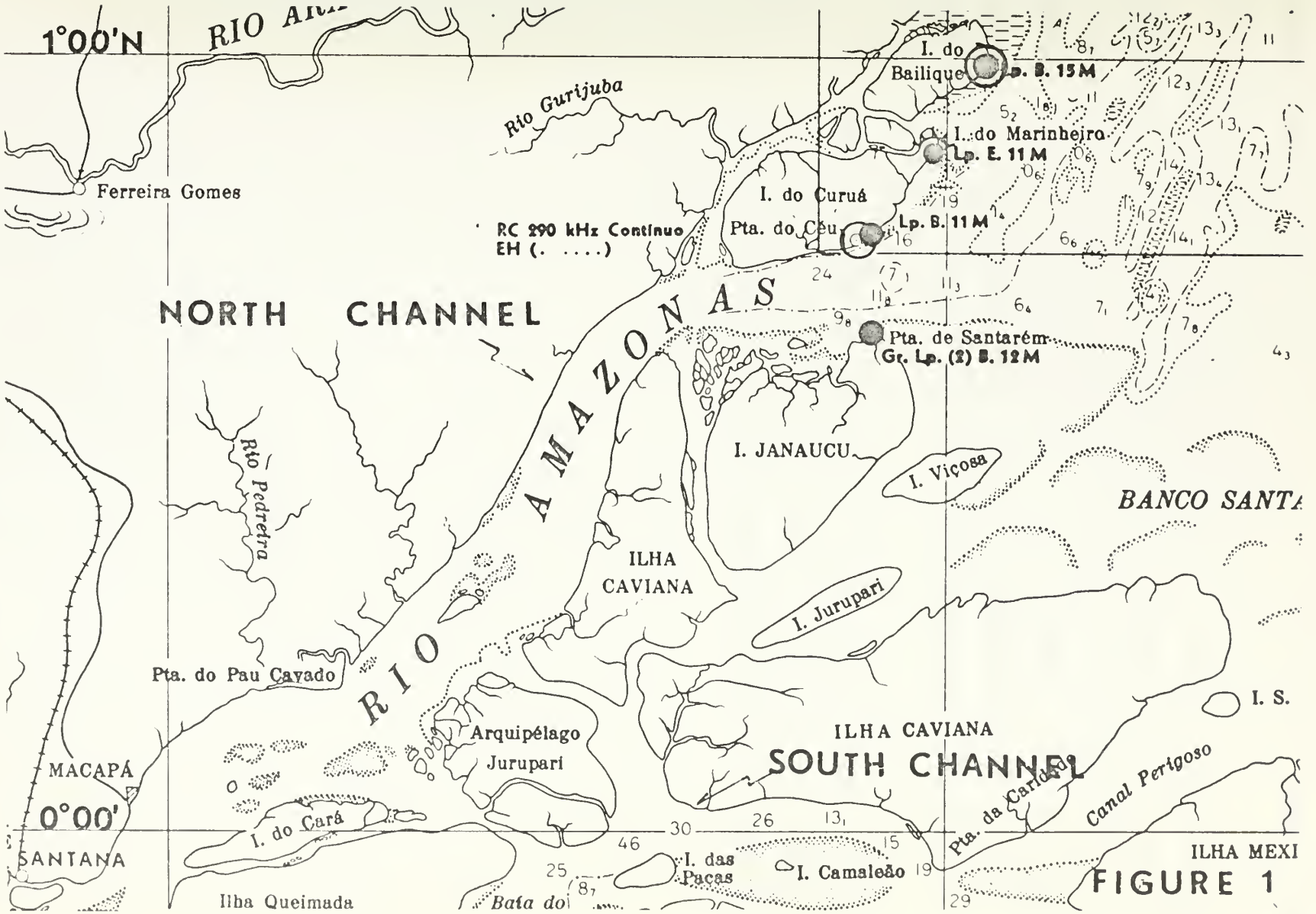

1°00'N
RIO AM
Rio Gurijuba
I. do
Bailique
Lp. B. 15M
I. do Marinheiro
Lp. E. 11M
Ferreira Gomes
I. do Curuá
Pta. do Céu
Lp. B. 11M
RC 290 kHz Continuo
EH (. ....)
NORTH CHANNEL
RIO AMAZONAS
Pta. de Santarém
Gr. Lp. (2) B. 12M
I. JANAUCU
I. Viçosa
BANCO SANTA
Rio Pedreira
ILHA
CAVIANA
I. Jurupari
Pta. do Pau Cavado
RIO
Arquipélago
Jurupari
ILHA CAVIANA
SOUTH CHANNEL
I. S.
MACAPÁ
0°00'
I. do Cará
Canal Perigoso
Pta. da Caridade
SANTANA
I. das
Paças
I. Camaleão
ILHA MEXI
Ilha Queimada
Bata do

FIGURE 1

small vessels and typical river boats load and unload passengers and light cargoes.

The Channel is generally oriented in a SW-NE direction, has an average depth of 20 m and is never narrower than 5.5 km. In some places, as in the vicinity of Macapa, the configuration of the river bed is quite variable, with irregular cross-sections and bottom topography. The bottom is composed mainly of mud and sand, and the banks and bars along the river are also of these materials.

A tidal bore does not manifest itself in the North Channel, but in the shallow sites near the mouth of the small tributaries and channels discharging into the main river bores are of very common occurrence.

III. THE HANSEN HYDRODYNAMICAL MODEL

A. ASSUMPTIONS AND BASIC EQUATIONS

The assumptions leading to a Hansen-type hydrodynamical model are the following:

1. The fluid is homogeneous and incompressible;
2. Pressure is hydrostatic, and thus the changes in pressure are due solely to changes in water surface elevation;
3. Advection terms are neglectable;
4. The fluid is in hydrostatic equilibrium in the vertical direction; and
5. The geographical and vertical variations of the Coriolis force may be neglected.

The basic equations for the single layer hydrodynamical model developed by Hansen follow from the application of these assumptions to the equations of conservation of momentum. Reference [10] presents the derivation of the equations.

Horizontal momentum equations are integrated over depth to give:

$$\frac{\delta U}{\delta t} - fV = - g \frac{\delta \zeta}{\delta x} + K\nabla^2 U - \frac{\tau^b(x)}{H} + \frac{\tau(x)}{H} + X \qquad (1)$$

$$\frac{\delta V}{\delta t} + fU = - g \frac{\delta \zeta}{\delta y} + K\nabla^2 V - \frac{\tau^b(y)}{H} + \frac{\tau(y)}{H} + Y \qquad (2)$$

$$\frac{\delta \zeta}{\delta t} + \frac{\delta}{\delta x}(HU) + \frac{\delta}{\delta y}(HV) = 0 \qquad (3)$$

The wind stress components are represented by:

$$\tau_{(x)} = \lambda W_x [W_x^2 + W_y^2]^{1/2} \quad (4)$$

$$\tau_{(y)} = \lambda W_y [W_x^2 + W_y^2]^{1/2} \quad (5)$$

The bottom stress components are given by:

$$\tau^b(x) = r\,U\,[U^2 + V^2]^{1/2} \quad (6)$$

$$\tau^b(y) = r\,V\,[U^2 + V^2]^{1/2} \quad . \quad (7)$$

The various terms in the above equations being defined as:

K = coefficient of horizontal kinematic eddy viscosity

λ = drag coefficient

W_x, W_y = wind speed components

ζ = surface elevation

H = total depth ($H = h + \zeta$)

g = acceleration of gravity

f = Coriolis parameter

x, y = space coordinates

X, Y = components of external forces

U, V = water velocity components
($U = \frac{1}{H}\int_{-h}^{\zeta} u\,dz$, $V = \frac{1}{H}\int_{-h}^{\zeta} v\,dz$)

r = bottom friction coefficient

∇ = $\frac{\delta}{\delta x} + \frac{\delta}{\delta y}$

The equations for bottom friction and wind stress are empirically developed. The wind stress terms as used in the model are assumed to be quadratic expressions in wind velocity, where λ is the wind drag coefficient with a typical value of

3.2×10^{-6} [6, 7, 10]. The bottom stress is assumed to be nonlinearly dependent on U and V, and like the wind stress it was derived by empirical means. It was originally formulated for a shallow water application and the use of this value for deep water is questionable, since it probably should be smaller in such an application. The value of r for this particular case was recommended by Laevastu (personal communication) as 2.8×10^{-3} to 3.0×10^{-3}.

B. FINITE DIFFERENCE EQUATIONS

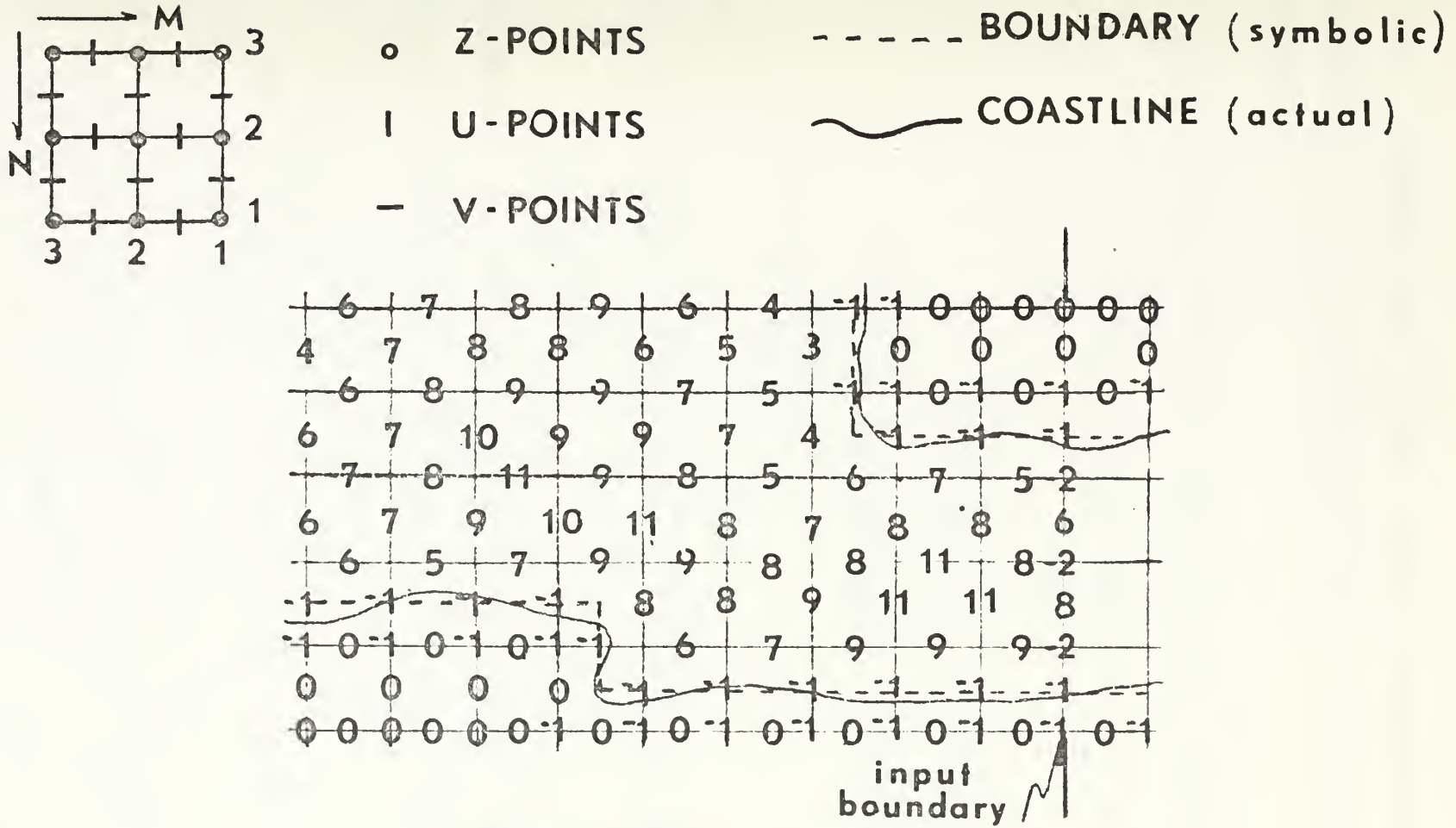
The differential equations are solved by a "leapfrog" or central-difference scheme for time dependent solutions. At the boundaries the values of the velocity components and surface elevation are taken at actual points rather than from the surrounding points as shown in Fig. 2.

The driving forces are the tides at the open boundaries and the wind at the surface over the entire field. The tidal values are computed at each time step and introduced as new values of ζ at each point on the boundary.

The finite-difference form of the equations is given below. Using the equation of conservation of mass, the water elevation is first calculated:

$$\zeta^{t+\tau}(n,m) = \bar{\zeta}^{t-\tau}(n,m) - \frac{\tau}{\ell}[H_u^t(n,m)\ U^t(n,m) - H_u^t(n,m-1)\ U^t(n,m-1)$$

$$+ H_v^t(n-1,m)\ V^t(n-1,m) - H_v^t(n,m)\ V^t(n,m)] \qquad (8)$$



GRID NET SCHEME

FIGURE 2

The horizontal and vertical velocity components are then determined from the respective horizontal and vertical momentum equations:

$$U^{t+2\tau}(n,m) = [1 - (2\tau r / H_u^{t+2\tau}(n,m))(\bar{U}^t(n,m)^2 + \overset{*}{V}^t(n,m)^2)^{1/2}]\bar{U}^t(n,m)$$
$$+ 2\tau f\overset{*}{V}^t(n,m) - \frac{\tau g}{\ell}[\zeta^{t+\tau}(n,m+1) - \zeta^{t+\tau}(n,m)]$$
$$+ 2\tau X^{t+2\tau}(n,m) \qquad (9)$$

$$V^{t+2\tau}(n,m) = [1 - (2\tau r / H_v^{t+2\tau}(n,m))(\bar{V}^t(n,m)^2 + \overset{*}{U}^t(n,m)^2)^{1/2}]\bar{V}^t(n,m)$$
$$- 2\tau f\overset{*}{U}^t(n,m) - \frac{\tau g}{\ell}[\zeta^{t+\tau}(n,m) - \zeta^{t+\tau}(n+1,m)]$$
$$+ 2\tau Y^{t+2\tau}(n,m) \qquad (10)$$

where:

$$\bar{U}^t(n,m) = \alpha U^t(n,m) + \frac{1-\alpha}{4}[U^t(n-1,m) + U^t(n+1,m) + U^t(n,m+1)$$
$$+ U^t(n,m-1)] \qquad (11)$$

$\bar{V}^t(n,m)$ and $\zeta^t(n,m)$ have expressions analogous to $\bar{U}^t(n,m)$,

$$\overset{*}{U}^t(n,m) = \frac{1}{4}[U^t(n,m-1) + U^t(n+1,m-1) + U^t(n,m) + U^t(n+1,m)],$$

and $\overset{*}{V}^t(n,m)$ is similarly analogous to $\overset{*}{U}^t(n,m)$. (12)

The time step is 2τ. The total depth H_u or H_v at u- or v-points is computed as:

$$H_{u\ (or\ v)}^{t\ +\ 2\tau}(n,m) = h_u(n,m) + \frac{1}{2}[\zeta^{t+\tau}(n,m) + \zeta^{t+\tau}(n,m+1)] \qquad (13)$$

The effects of wind are computed by:

$$X^t = \frac{\lambda}{H} W_x^t \left[\left(W_x^t \right)^2 + \left(W_y^t \right)^2 \right]^{1/2} - \frac{1}{\rho} \frac{\delta P}{\delta x}. \quad (14)$$

$$Y_t = \frac{\lambda}{H} W_y^t \left[\left(W_x^t \right)^2 + \left(W_y^t \right)^2 \right]^{1/2} - \frac{1}{\rho} \frac{\delta P}{\delta y}. \quad (15)$$

where P_o is the barometric pressure. It is assumed that the pressure gradient is zero for small areas and normal conditions.

The stability of the finite-difference scheme is governed by the Courant-Friedrich-Levy criterion which states that the maximum length of the time step is determined by the grid size, ℓ, and maximum depth, H_{max}:

$$\Delta t = \frac{\ell}{\sqrt{2gH_{max}}} \quad (16)$$

For this particular grid, a value of 30 seconds was used for the one-half time step, Δt.

When the computational area contains small regions of great depth, a "false-bottom" can be used in these sections [7]. For example, areas deeper than 500 m may be assumed to be 500 m deep. This will often result in a considerable increase in time step or a decrease in the grid length if total computation time is a critical factor. Experimental results have shown that the errors introduced with this procedure are acceptable in some cases for practical applications of the model.

The grid net is formed by three different sets of points as shown in Fig. 2, the water elevation (Z-points) and the two components of the velocity (U- and V-points). Each of these points has the same coordinate designation (N,M).

The coastline must pass through the U- and V-points and never through the Z-points. The program reads the values of the depth at U- and V-points as HTU and HTV, respectively.

The Z-points are for water, land and coast designation, being read by the program as HTZ. They are treated symbolically as 1, 0 and -1 respectively. The HTU and HTV show the chart depth in centimeters, while the coastline is symbolized by -1 and the land by 0, depending on their location in the grid. At the open boundaries the points HTZ have symbolic values of -2 and -3 for the first and second boundary when applicable. Outside these boundaries, values of 0 for HTZ are prescribed.

The coefficient of horizontal kinematic eddy viscosity is related to the values of the U and V components. Hansen states that the computations are always stable for values of $\beta = (1 - \alpha)$ between 0 and 0.5. This coefficient can also be used as a tuning factor: the higher the value, the smoother the current velocity distribution. In areas where the depth distribution is irregular, as in this case, accelerations and surface irregularities appear in the model. These abnormalities can be corrected for by means of a proper smoothing of the bottom or of the water surface elevation; in this model this is accomplished by smoothing the water surface elevation, which is a numerical artifact of the model.

In finite-difference form, the coefficient of horizontal kinematic eddy viscosity is given by the relation:

$$K = \frac{\Delta \ell^2 (1 - \alpha)}{4 \Delta t}$$

For this model with a value of alpha equal to 0.983 recommended by Laevastu (personal communication), K becomes 0.46×10^{-5} cm^2/sec.

High values of alpha must be used with caution, because these can allow undesirable oscillations in the model. Also, if too low a value is used to provide higher smoothing, the current velocity may be overly damped.

As was pointed out in the assumptions of the Hansen model, the mean advective terms, $u_j \delta u_i/\delta x_j$, have been neglected. This is not necessarily a good assumption as these terms can be the same order of magnitude as the local acceleration terms, $\delta u_i/\delta t$. In the derivation of the time averaged equations of motion, the turbulent contribution of the advective terms, as expressed by the Reynold's stresses, have been included using the linearizing eddy diffusivity approximation. Hence, the non-linear effects are not included but the amplitude effects of the advective terms are included by the eddy diffusivity approximation.

C. GRID SELECTION

The grid size is selected upon requirements of detail and accuracy and the availability of computer core memory and time. There is not a general rule for selection of the grid mesh, but for open areas and round smooth bays, where the expected values of current velocity and direction fields are smooth, a fine mesh is not necessary, but for areas where the topography is of primary importance, or in narrow channels, a fine mesh may be required for reliable results.

For this particular model, a medium size grid was initially considered satisfactory (see discussion on page 61 below). Decreasing the size of the mesh will result in an increase of time and computer memory. A 24 x 65 unit array of square mesh cells having sides 1800 m in length was laid over the North Channel of the Amazon River as it is represented in the Brazilian Nautical Chart No. 220 (BRASIL - RIO AMAZONAS, carta 220 "Da Barra Norte ao Porto de Santana," DHN - Rio de Janeiro).

Experiments performed at the Environmental Prediction Research Facility (EPRF) have proven that there is not much increase in accuracy for smaller grid size; for example, a model for the San Diego Bay was run under three different meshes, and except in computation of advection and dispersion of pollutants, no significant differences were recorded between fine and coarse grids.

D. INPUT OF TIDES AND RIVER DISCHARGE

The tides in this model were inputed at the northern opening in the grid which was chosen and oriented such that the closest tidal station in that location lay over or near a grid-point, along the M = 2 grid line. This tidal entrance is parallel to the y- coordinate.

The tides at the station LIMAO DO CURUA (Fig. 3) were introduced with seven components, M2, S2, N2, K2, L2, K1 and MS4. Two other tide stations provide means of comparison for the tides predicted by the HN-model: ACAITUBA and MACAPA, 58 km and 142 km upstream, respectively. Usually only four components are introduced in the model, but the values of the

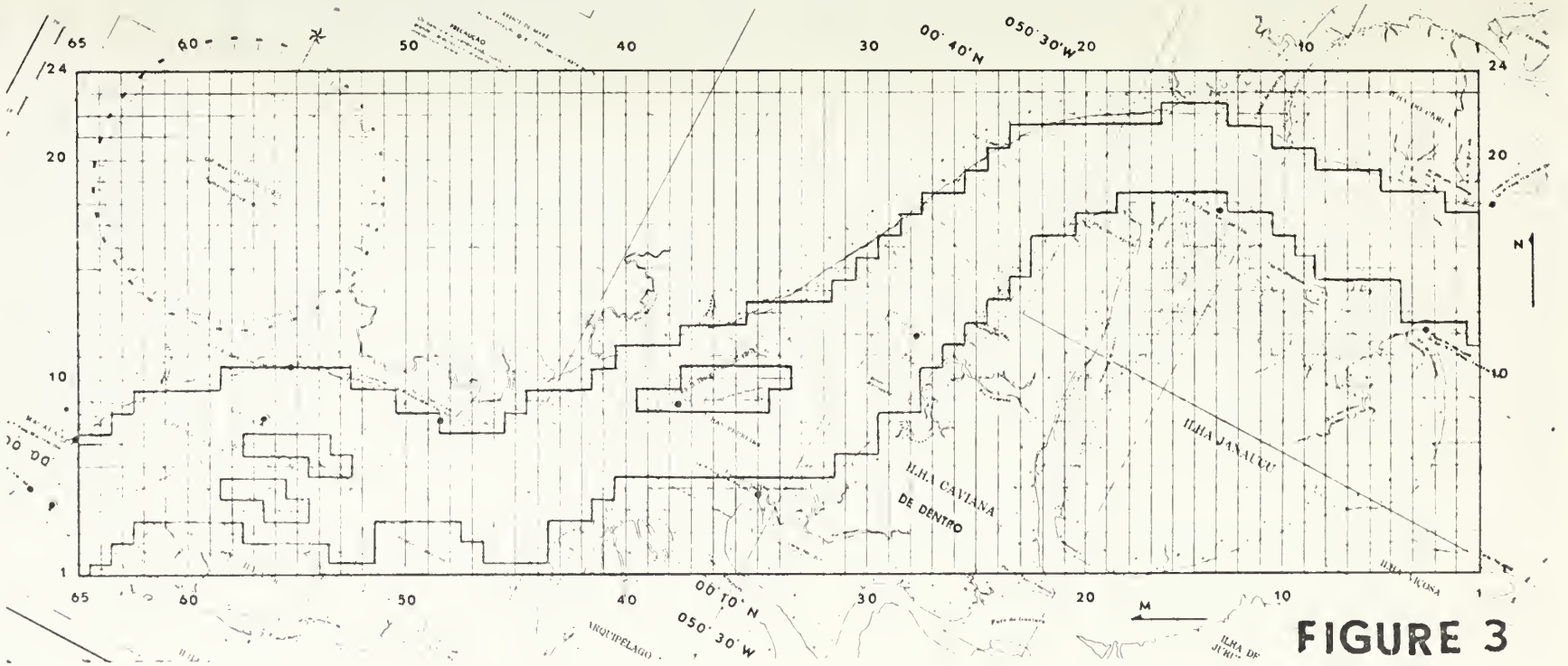


FIGURE 3

GRID-NET OVER THE AMAZON'S NORTH CHANNEL, AS IT IS REPRESENTED IN THE BRAZILIAN NAUTICAL CHART NO. 220. THE ARROWS LABELED "N" AND "M" INDICATE THE DIRECTION OF INCREASING N AND M GRID-COORDINATES.

seven constituents introduced in this particular case were considered quite significant.

The river discharge was inputed as permanent current, averaged from the bottom to the surface, in a cross-section near Macapa along the y-grid line at the southern end of the grid. This input boundary was left open to insure continuity.

There is no adequate measurement of the river discharge in the North Channel at the present time. There are, however, some estimates and calculations of the river discharge at Macapa and at the mouth and some current measurements made by the Brazilian Navy for navigation purposes. Table I shows a compilation of the more recent investigations and measurements for the Amazon's discharge.

The flow of the Amazon is seasonal and can be correlated with precipitation in the entire Amazon region. Diegues [3] states that during the year the variation of the level of the river is quite sufficient, the water level being closely related to precipitation in the Amazon Basin to a large degree and the melting of snow in the Andes Mountains to a small degree. Such variations are periodic and follow a yearly cycle.

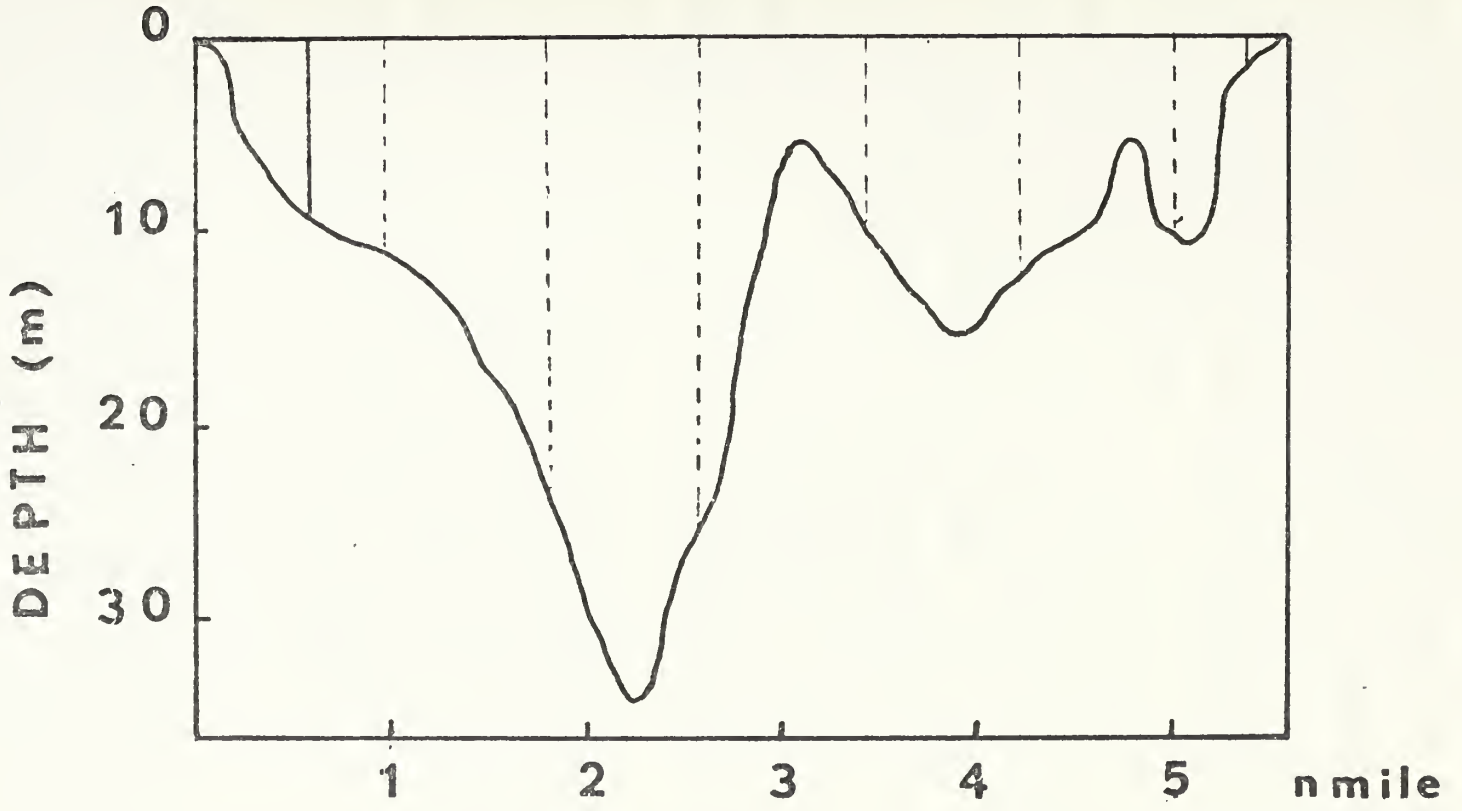
The value used for this model is an estimated averaged value for Macapa, 175,000 m^3/sec, and it is most generally accepted. Such value which is expected to represent the mean or intermediate stage for the river was distributed over the cross-section in Macapa, as shown in Fig. 4, to produce the mean velocities (permanent downstream flow) to be inputed in grid points, in a manner similar to that described by Dronkers [4].

Date	Location	River Stage	Width m	Area m^2	Mean Velocity m/sec	Discharge m^3/sec	Source
7-16-63	Obidos	High	2,290	110,000	1.97	216,000	Oltman, 1968
11-20-63	Obidos	Low	2,260	92,400	0.79	72,500	Oltman, 1968
8- 9-64	Obidos	Mean	2,280	106,000	1.55	165,000	Oltman, 1968
7-20-63	Manaus	High	2,097	85,654	1.74	169,104	Souza et al, 1964
7-22-63	Manaus	High	683	14,864	1.35	-	Souza et al, 1964
1967	Mouth[1]	Low	12,500	270,000	0.30	83,500	Gibbs, 1972
1967	Mouth[1]	High	12,500	310,000	0.90	267,400	Gibbs, 1972
1963	Macapa[2]	High	11,204	186,218	1.14	212,378	Souza et al, 1964
1963	Mouth[2]	Mean	-	-	-	175,000	Oltman, 1968

[1] At the isohaline of 20%

[2] Estimative

TABLE I - Compilation of some discharge measurements and investigations in the Amazon River and Estuary.



AMAZON CROSS-SECTION NEAR MACAPA LOOKING DOWNSTREAM

FIGURE 4

E. TUNING THE MODEL

Tuning the model is a matter of patience. Several runs of the program were made with different combinations of alpha and the bottom friction parameter. After each run both the water elevation and currents were compared to harmonic method and current measurements available. The model is left to run for some hours of real time with these combinations of parameters until stability is attained.

In general, the model appears to be rather insensitive to variations in the bottom friction coefficient, but it responds quickly to small variations in alpha. The behavior of the tidal curve at the same location for two different values of alpha ($\alpha = 0.980$, $\alpha = 0.975$) and two different values of bottom friction parameter ($r = 0.0028$, $r = 0.0030$), is illustrated in Fig. 5. When changing alpha the bottom friction parameter was maintained constant and vice-versa.

Due to a lack of adequate current measurements in the North Channel the model was mainly adjusted for the tides, and the velocities of the currents were considered satisfactory when the tide agreement was reached and the currents approached the values and directions of the few available observations.

F. MODEL

The calculated currents behave as described by Franco [8], that is, they are what is termed "alternating-axial" or sometimes "rectilinear" or "reversing." The maximum downstream velocities appear at low tide (LT) and they are greater at the first LT than in the second. Similarly, maximum upstream

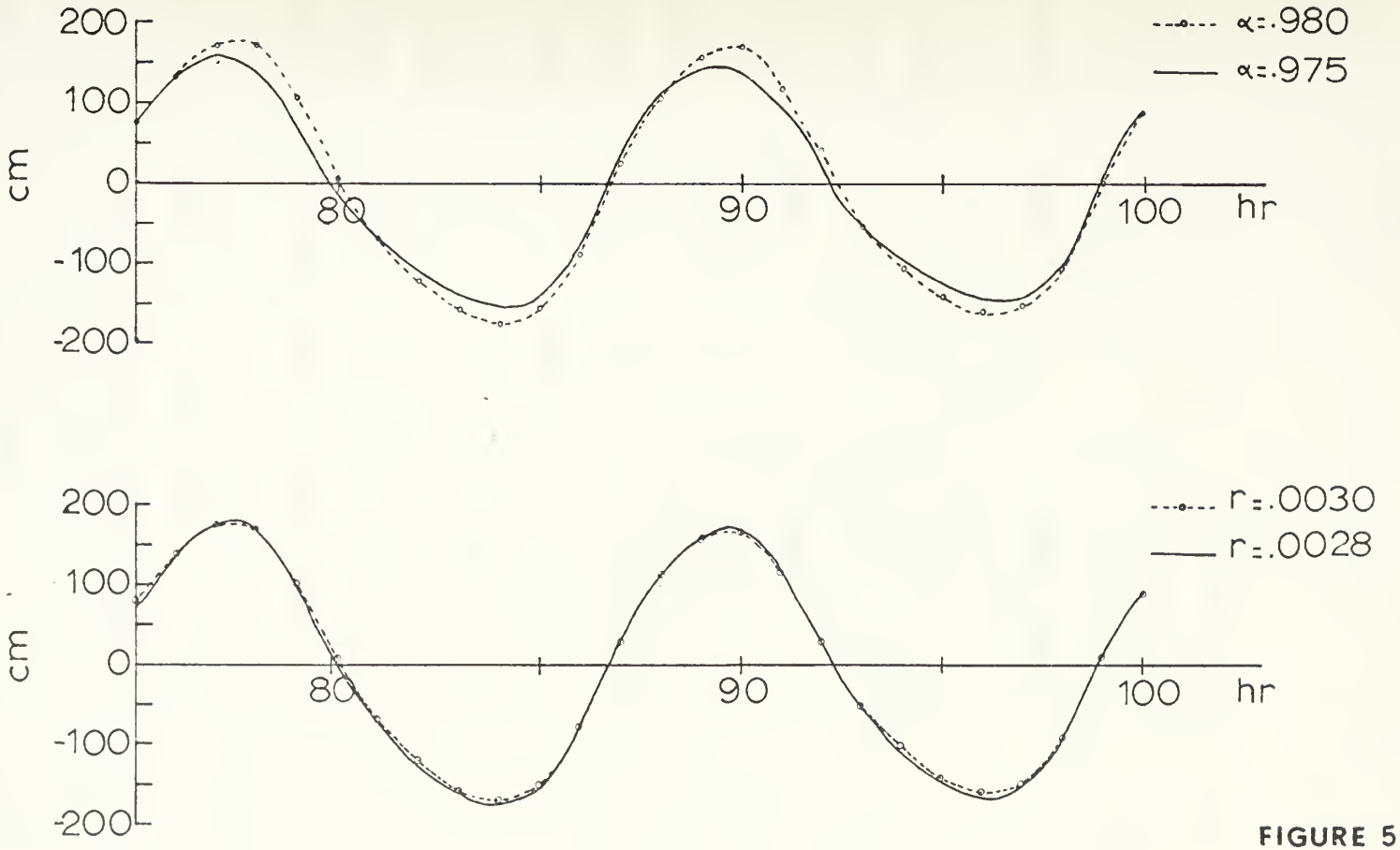


FIGURE 5

TUNING THE MODEL: ABOVE, ALPHA IS CHANGED AND THE FRICTION COEFFICIENT, r, IS MAINTAINED CONSTANT; BELOW, ALPHA IS CONSTANT AND r IS CHANGED.

velocities occur at the high tide (HT). Slack water corresponds to the crossings of the mean level.

At the grid points representing the tidal stations, the respective maximum and minimum predicted values of current were as follows:

(1) At Limao do Curua, grid coordinates (17,2), 196 cm/sec and 183 cm/sec for the first and second LT and 162 cm/sec and 157 cm/sec for the first and second HT. The direction changed from 062° (downstream) to 242° (upstream).

(2) At Acaituba, grid coordinates (11,26), 115 cm/sec and 107 cm/sec for the first and second LT and 90 cm/sec and 87 cm/sec for the first and second HT. The direction changed from 032° (downstream) to 210° (upstream).

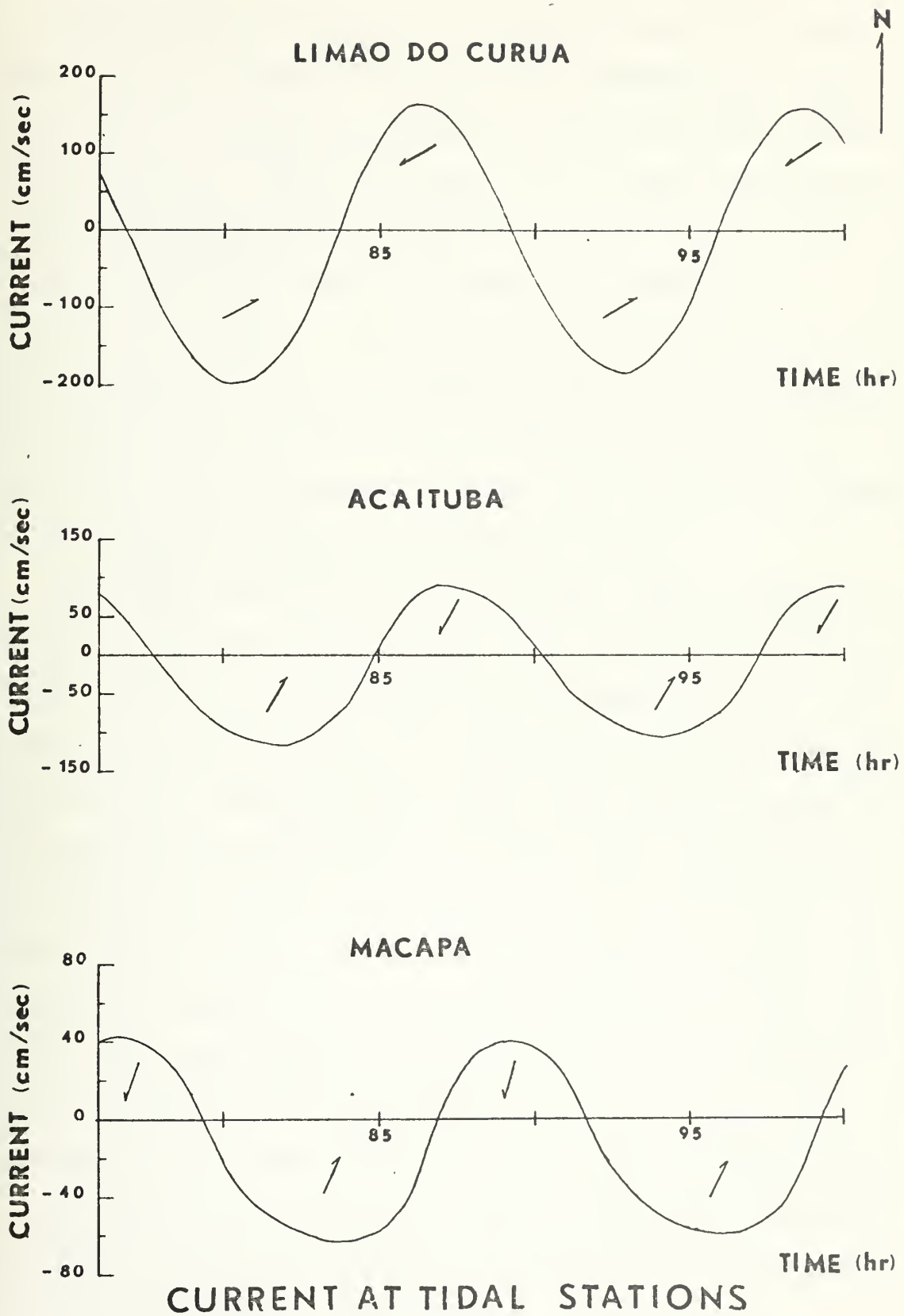
(3) At Macapa, grid coordinates (7,63), 62 cm/sec and 60 cm/sec for the first and second LT and 42 cm/sec and 40 cm/sec for the first and second HT. The direction changed from 024° (upstream) to 201° (downstream).

At these locations a phase lag of about 40 minutes between the instant of the high tide and low tide and the peak of the current is observed, but it is possible that this lag may be smaller, since the output of one hour interval of the program did not allow a precise determination of the exact instant of the low and high tide (Table II).

Figure 6 shows a plot of the current velocities at the three mentioned tide stations for the last 24 hours for a simulated 100 hours (real time) run of the program.

TIME	LIMAO DO CURUA			ACAITUBA			MACAPA		
hr	VEL cm/sec	DIR o		VEL cm/sec	DIR o		VEL cm/sec	DIR o	
76	73	242		80	210		40	196	<HT
77	11	062		43	211		42	220	
78	100	061		11	027		33	206	
79	165	062		60	031		13	202	
80	196	062	<LT	91	031		21	029	
81	192	063		109	032		43	026	
82	151	061		115	032	<LT	54	025	
83	75	062		103	032		60	024	<LT
84	29	242		65	033		62	024	
85	121	242		12	203		58	024	
86	162	242	<HT	71	209	<HT	41	024	
87	150	240		90	209		5	174	
88	98	242		84	210		32	194	
89	25	242		58	210		40	201	<HT
90	60	061		13	213		36	206	
91	132	062		41	030		21	200	
92	174	060	<LT	76	031		9	049	
93	183	062		97	031		35	029	
94	158	062		107	032	<LT	49	027	
95	98	062		103	032		56	026	<LT
96	6	060		76	032		60	026	
97	93	240		16	037		58	026	
98	151	242	<HT	56	209		47	027	
99	157	242		86	209		12	043	
100	118	242		87	210		25	194	

TABLE II - Current velocity and direction predicted by the HN-model at the three tidal stations. The left-hand column indicates the last 24 hrs of a 100-hr (real time) computer run. The right-hand columns indicate the approximate time of the low tides (LT) and high tides (HT).



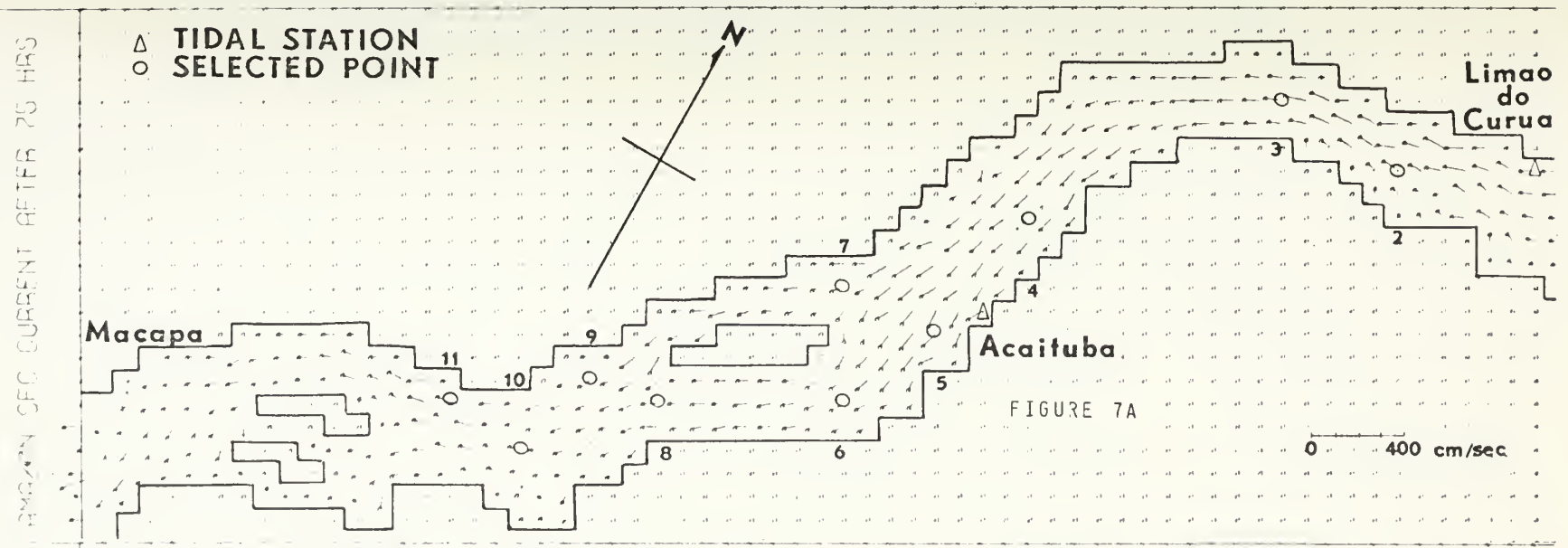
CURRENT AT TIDAL STATIONS

FIGURE 6

Plots of the currents in the North Channel are shown in Figs. 7 (a,b) through 19 in which the currents are scaled so that 1 cm corresponds to 157 cm/sec and the arrows indicate the directions. The full lines on the graphs represent the symbolic boundaries, the triangles represent the location of the tidal stations, and the ellipses the location of selected points. (It should be noted that the plotting subroutines used for these plots are not included in the program of Appendix A.) The water elevation and the resultant current velocity at the selected points are shown in Table III, which is a reproduction of the computer output for the special points.

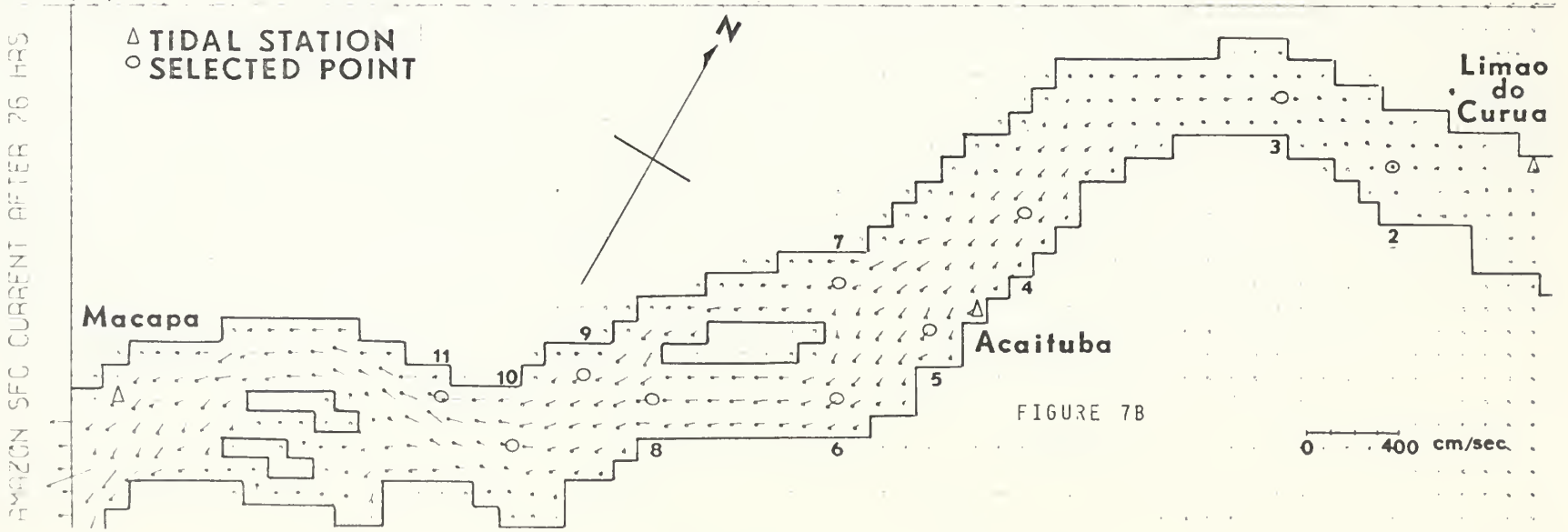
The tides predicted by the model are shown in Figs. 20 through 22 for the last 24 hours of a simulated 100 hours (real time) period. In these figures is included the difference between the prediction by the numerical model (HN) and the prediction by harmonic method (HM). For Limao do Curua (Fig. 20) the maximum difference was 19 cm which represents 4% of the tidal range and a phase lag of less than 30 minutes is observed only at the first LT. For Acaituba (Fig. 21) the maximum difference was 41 cm which represents 11.7% of the tidal range but a phase lag of about 20 minutes is observed between the HN and HM prediction. This can be partially explained by the fact that the actual tide station lies in much shallower water than the closest grid point chosen to represent it and also because the distance from this grid point to the station is about 2 km.

For Macapa (Fig. 20) the results were not satisfactory. An attempt to improve the results, by smoothing the bottom, resulted in the curve labeled HN1 in the figure, but further attempts were abandoned because they would not be realistic with the actual mesh size.



AMAZON SFC CURRENT AFTER 25 HRS

FIGURE 7A



AMAZON SFC CURRENT AFTER 25 HRS

FIGURE 7B

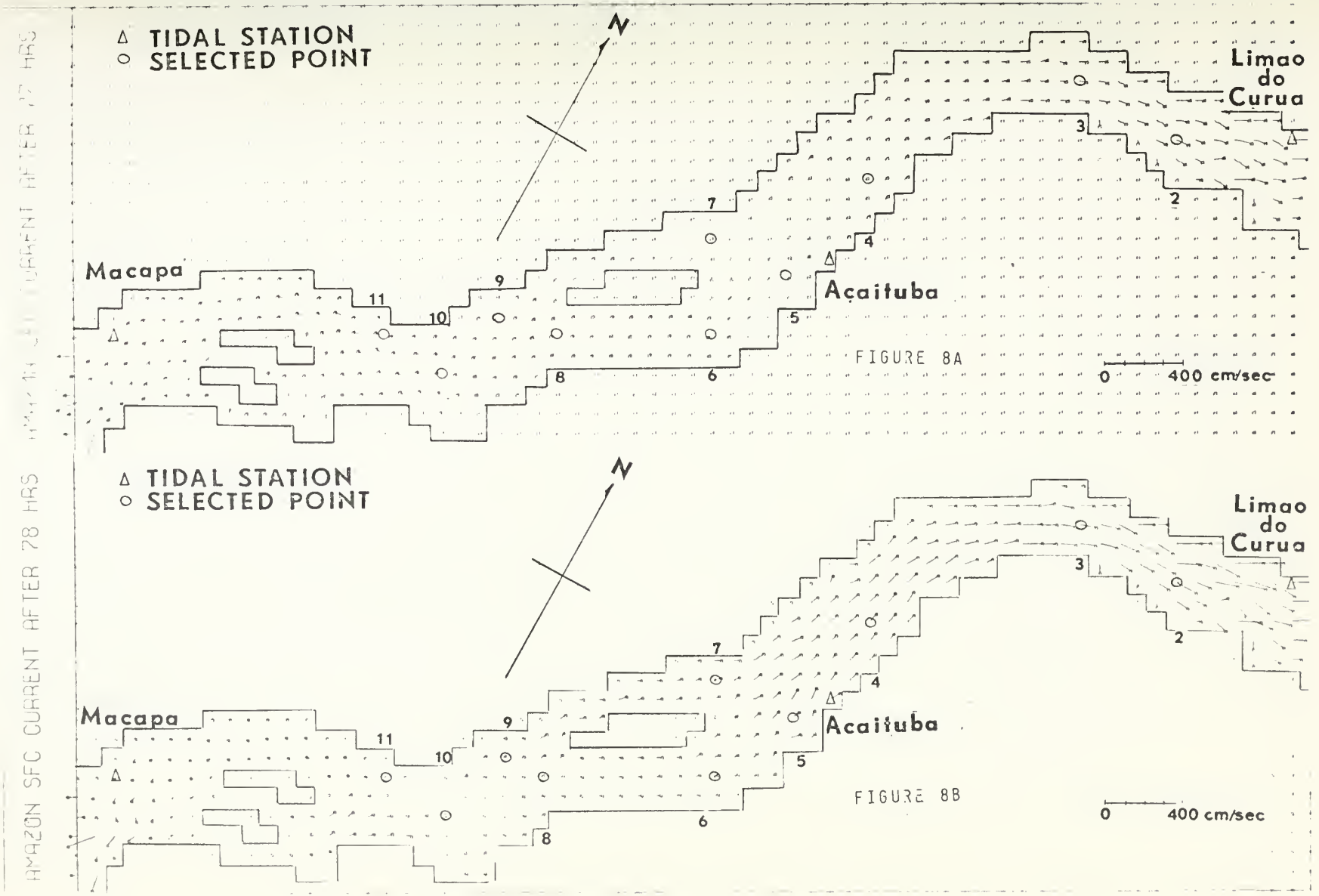


FIGURE 8A

FIGURE 8B

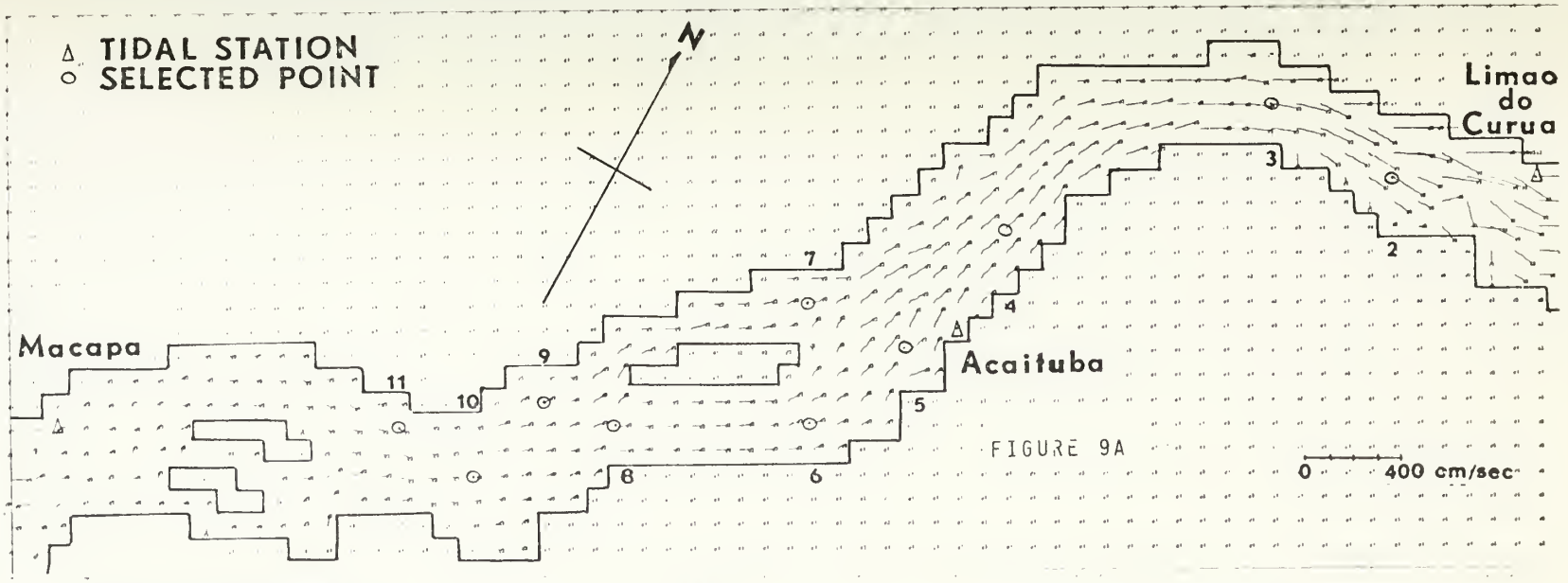


FIGURE 9A

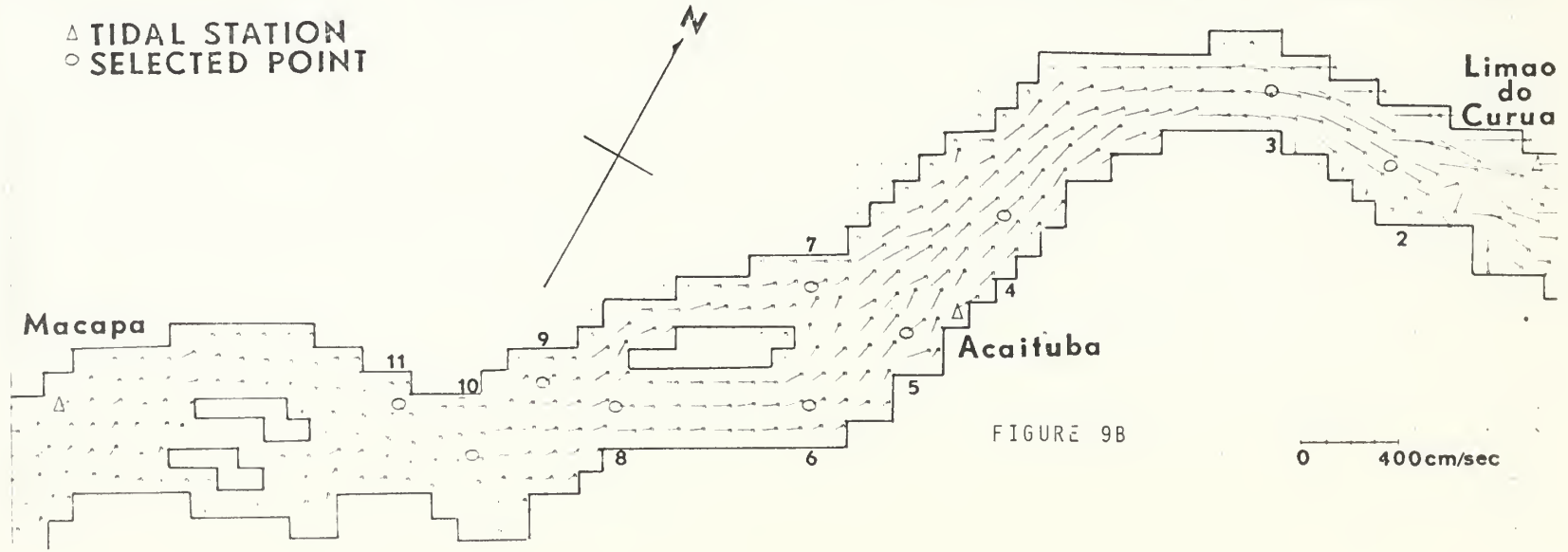


FIGURE 9B

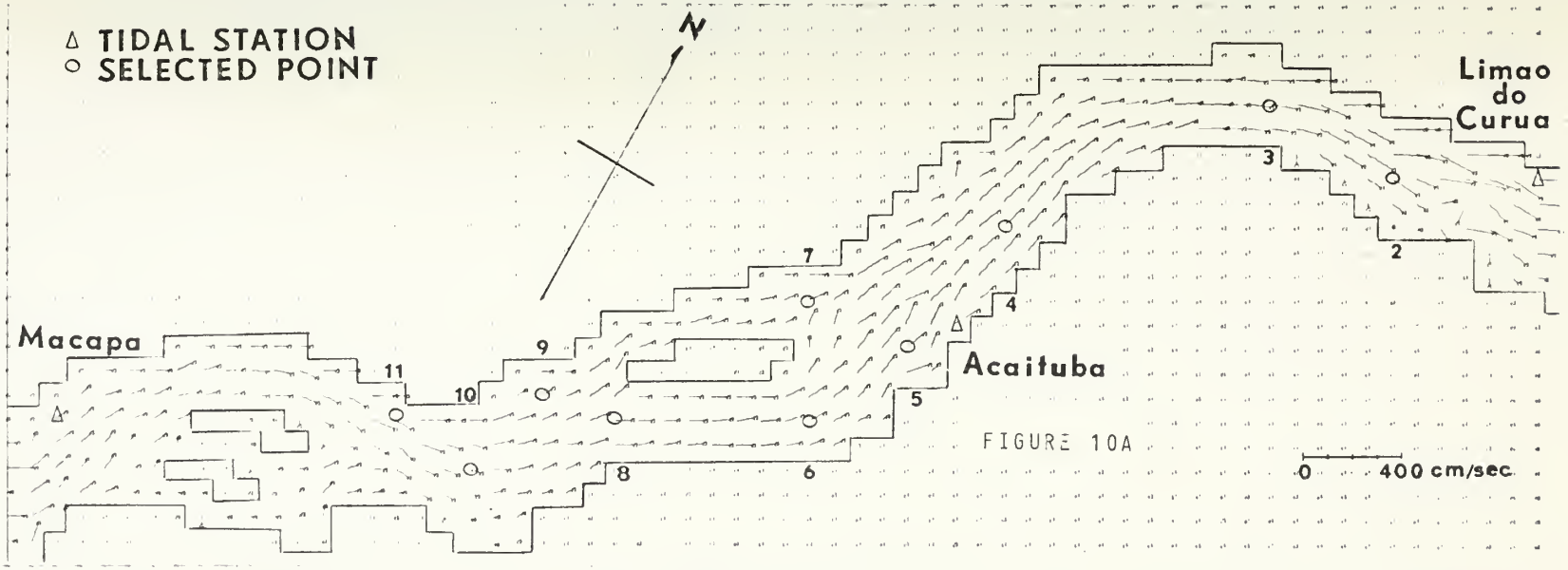


FIGURE 10A

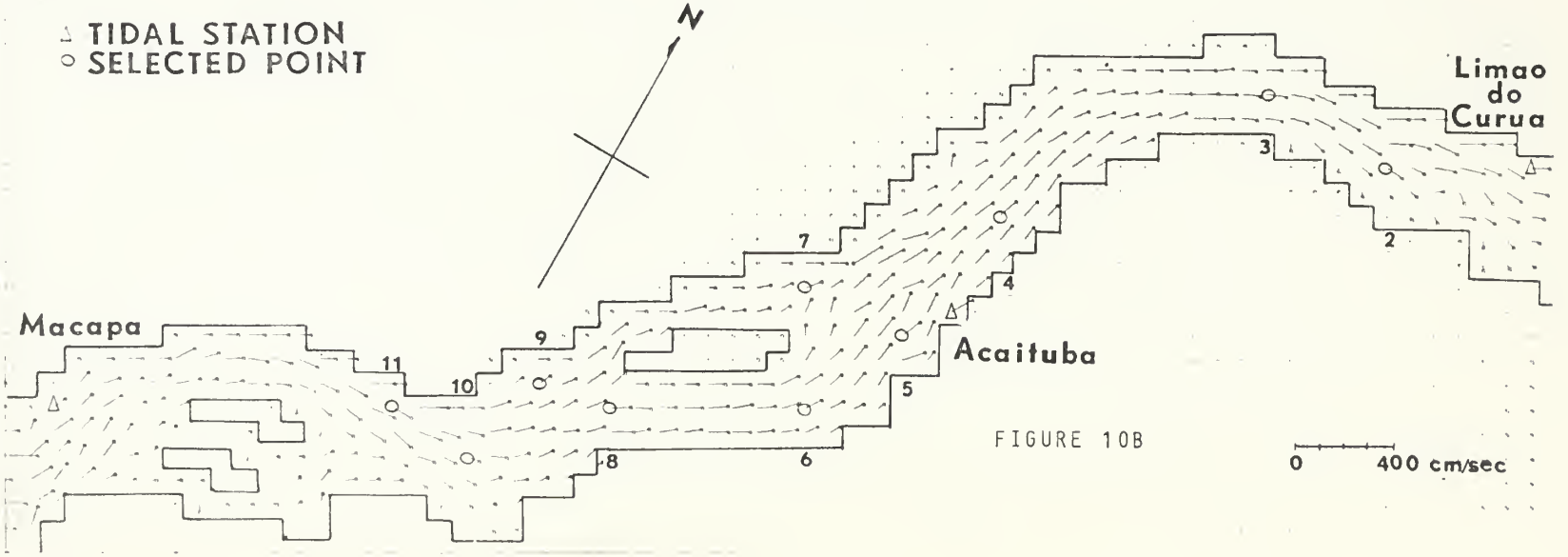


FIGURE 10B

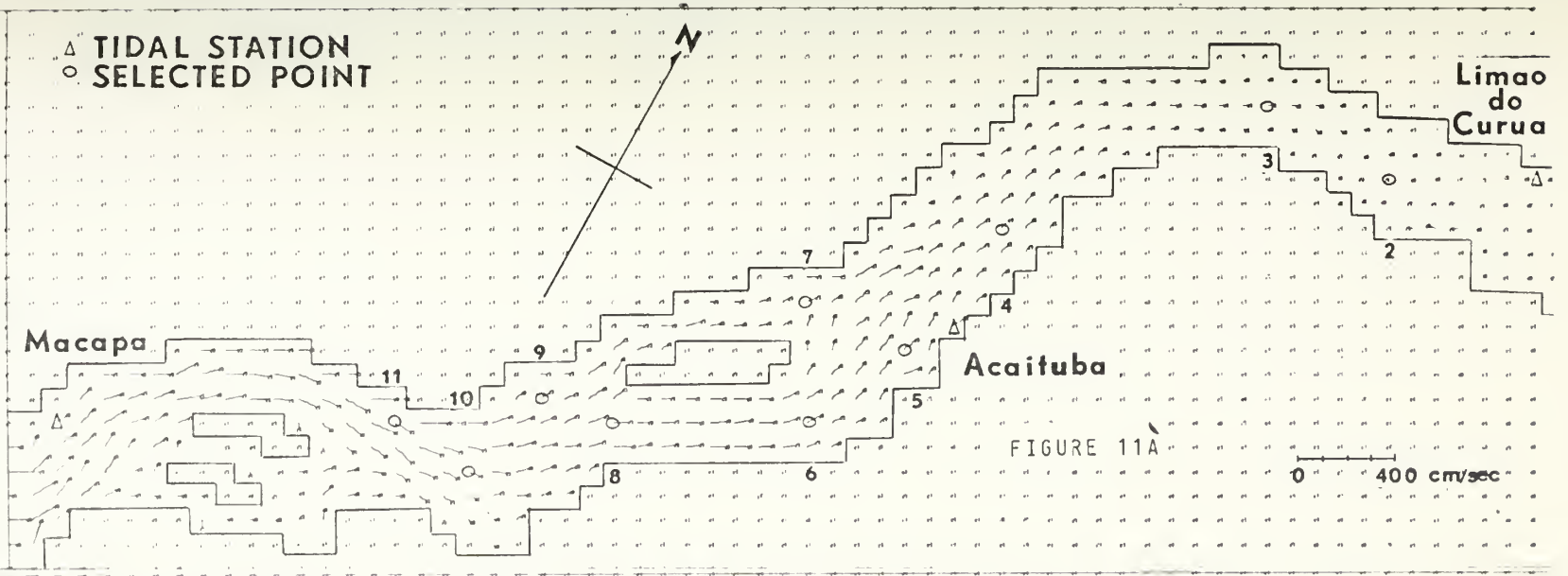


FIGURE 11A

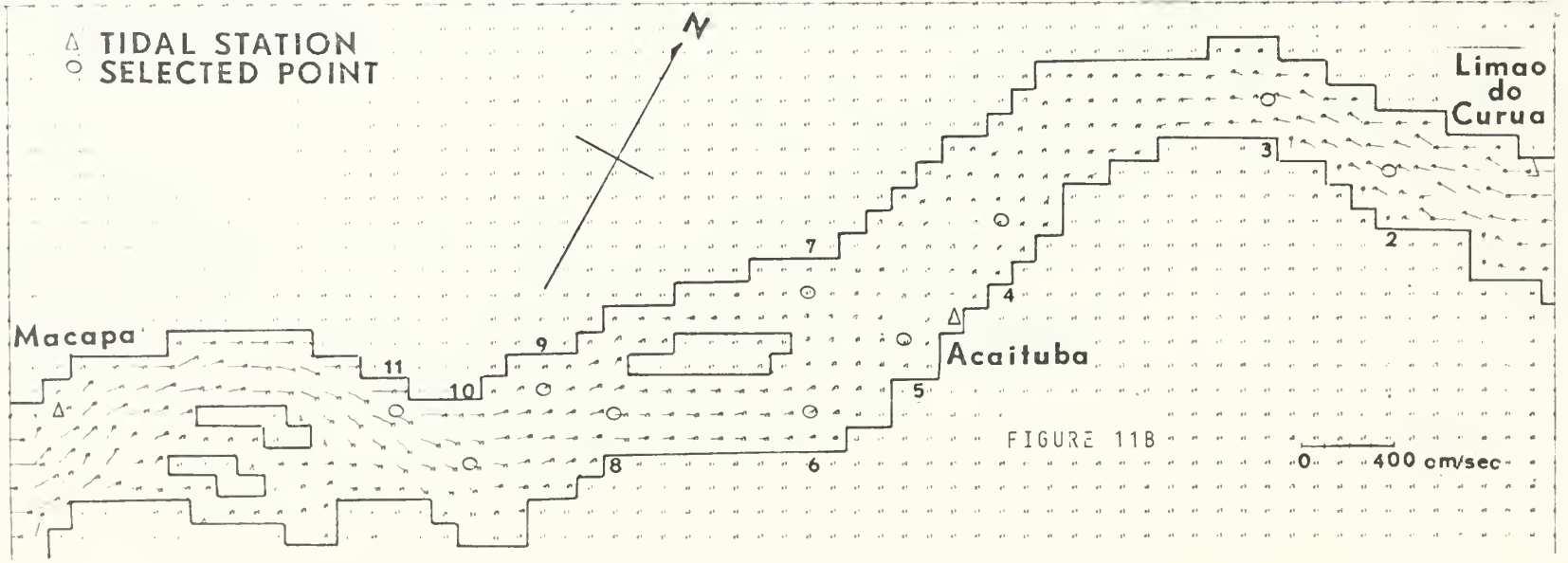


FIGURE 11B

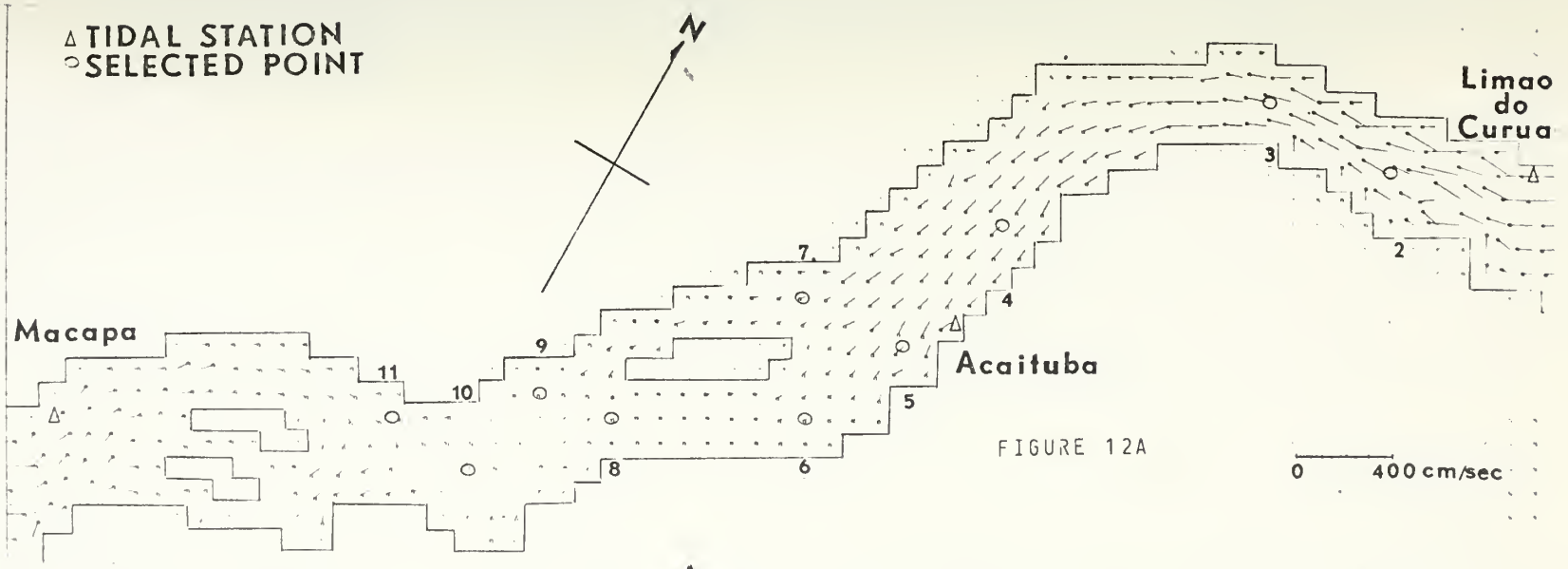


FIGURE 12A

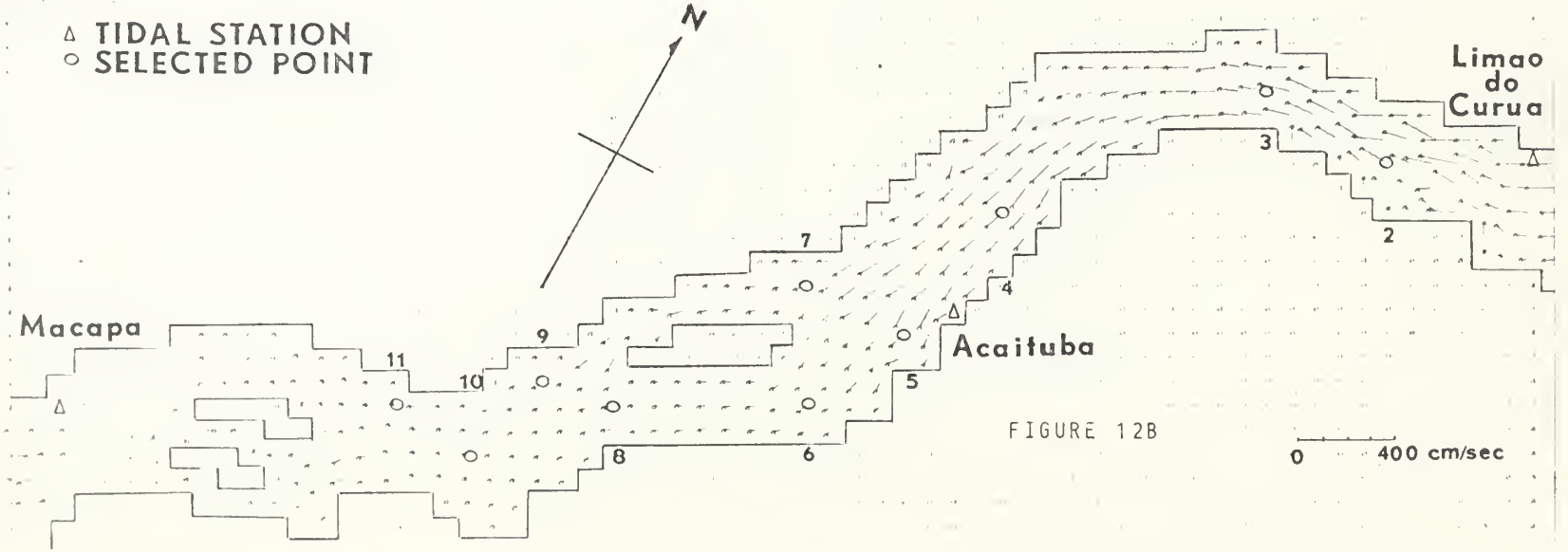


FIGURE 12B

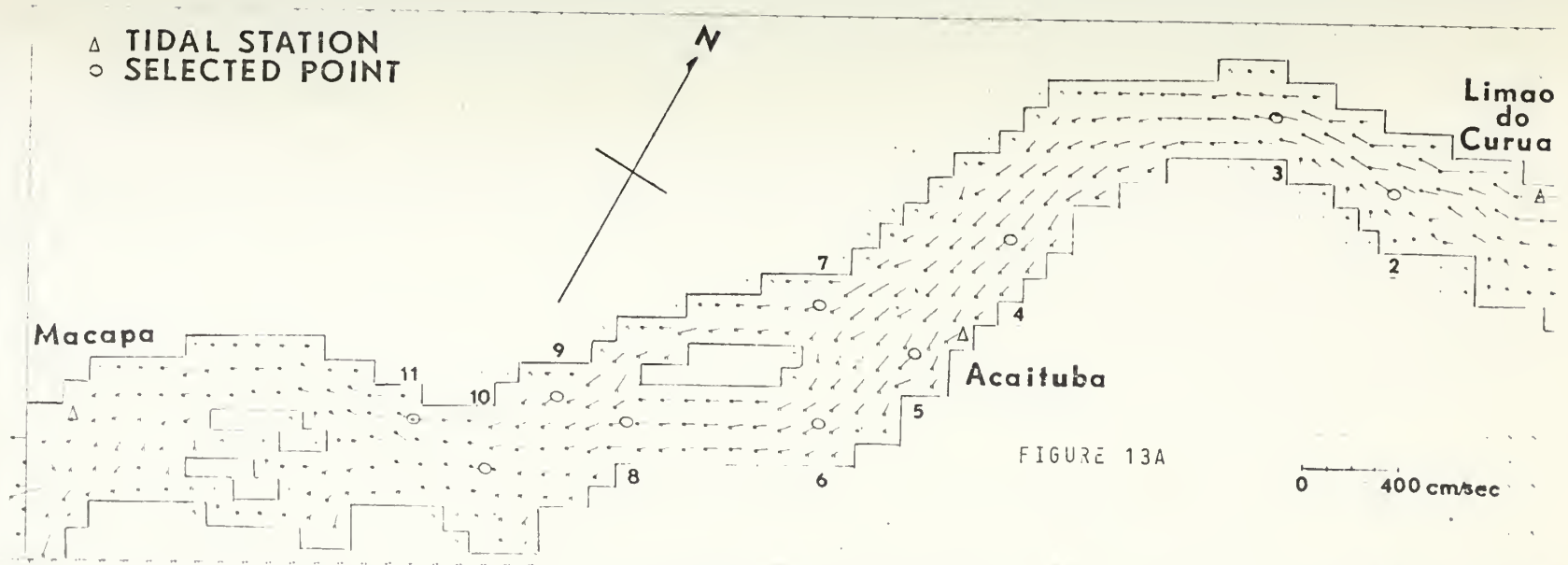


FIGURE 13A

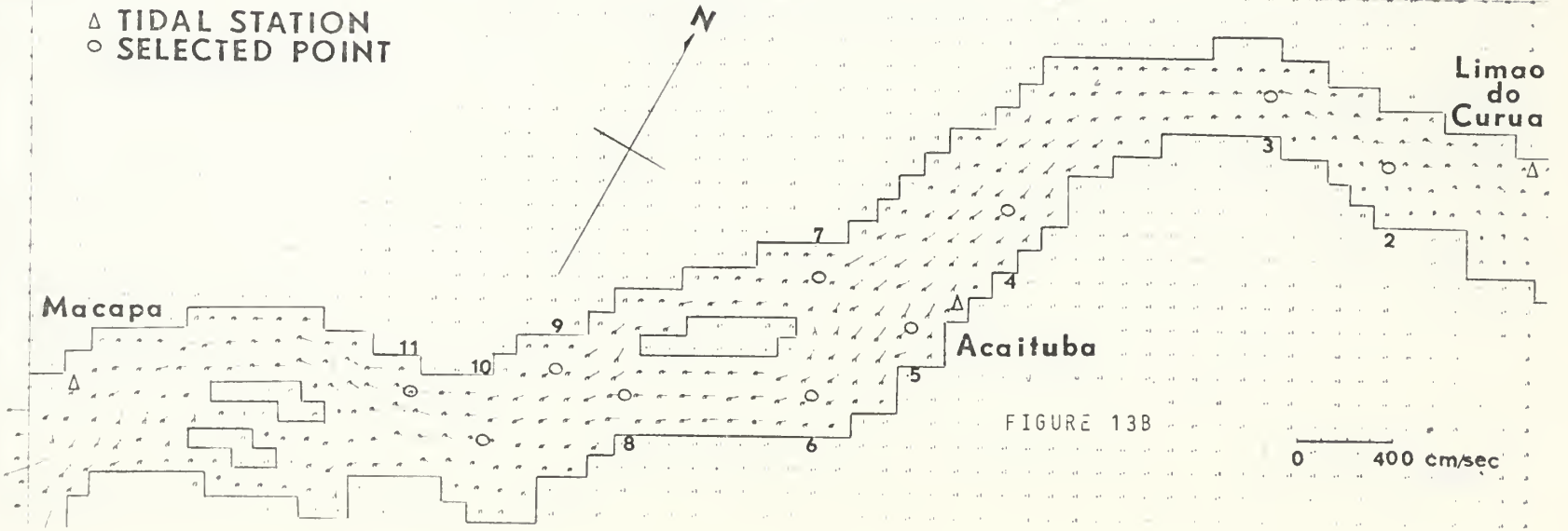


FIGURE 13B

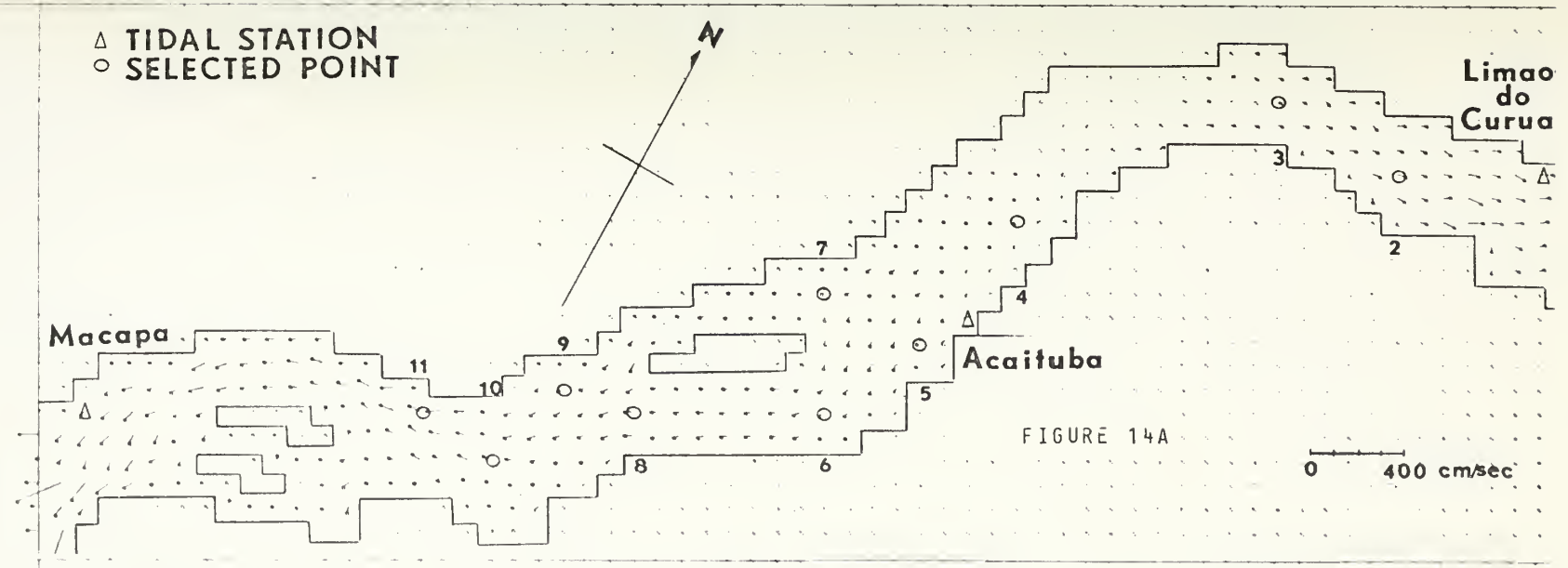


FIGURE 14A

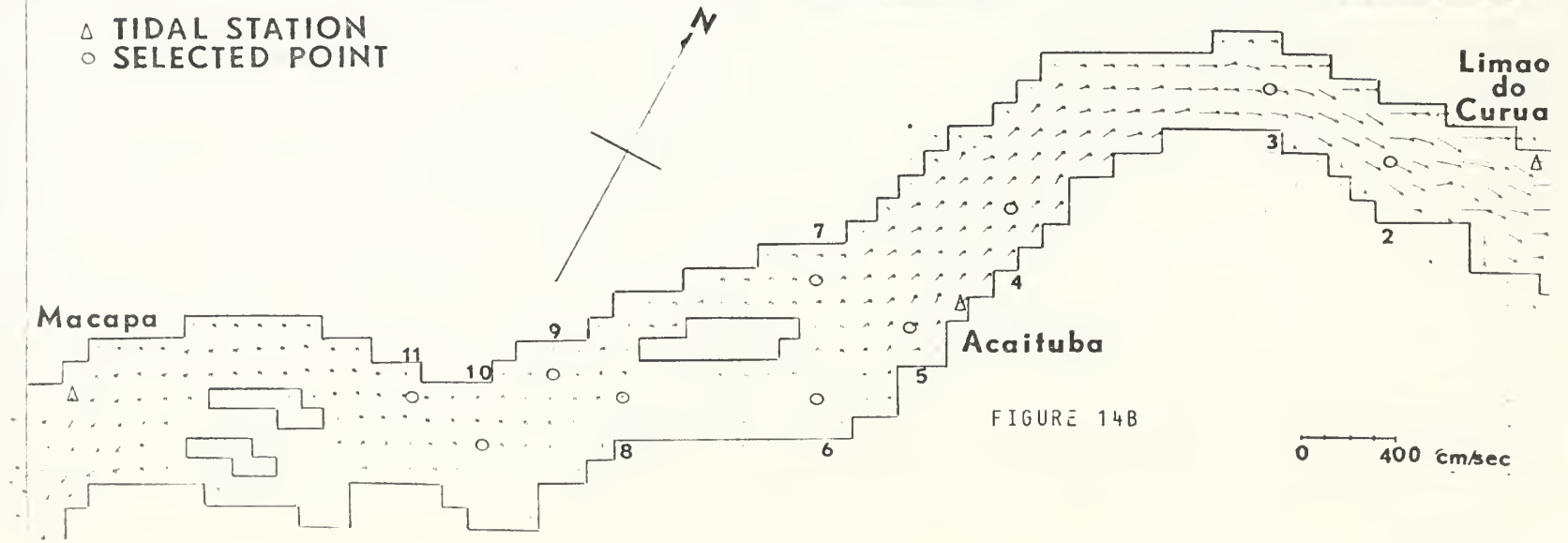


FIGURE 14B

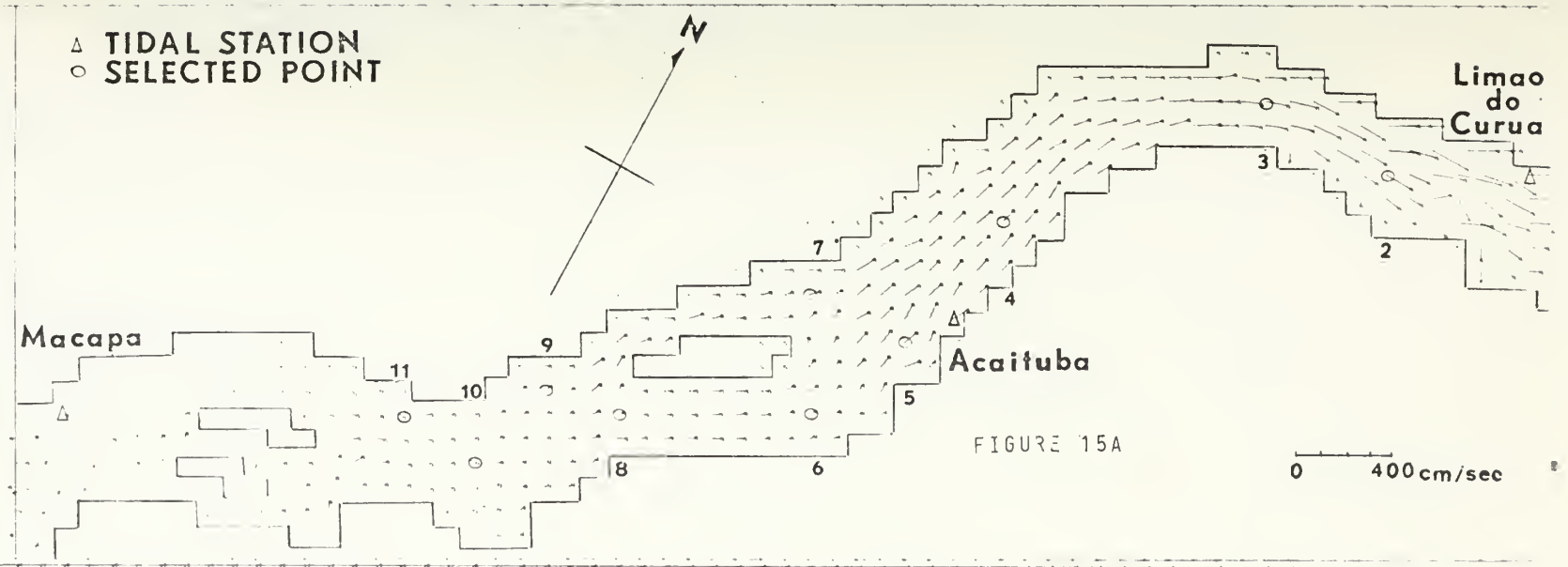


FIGURE 15A

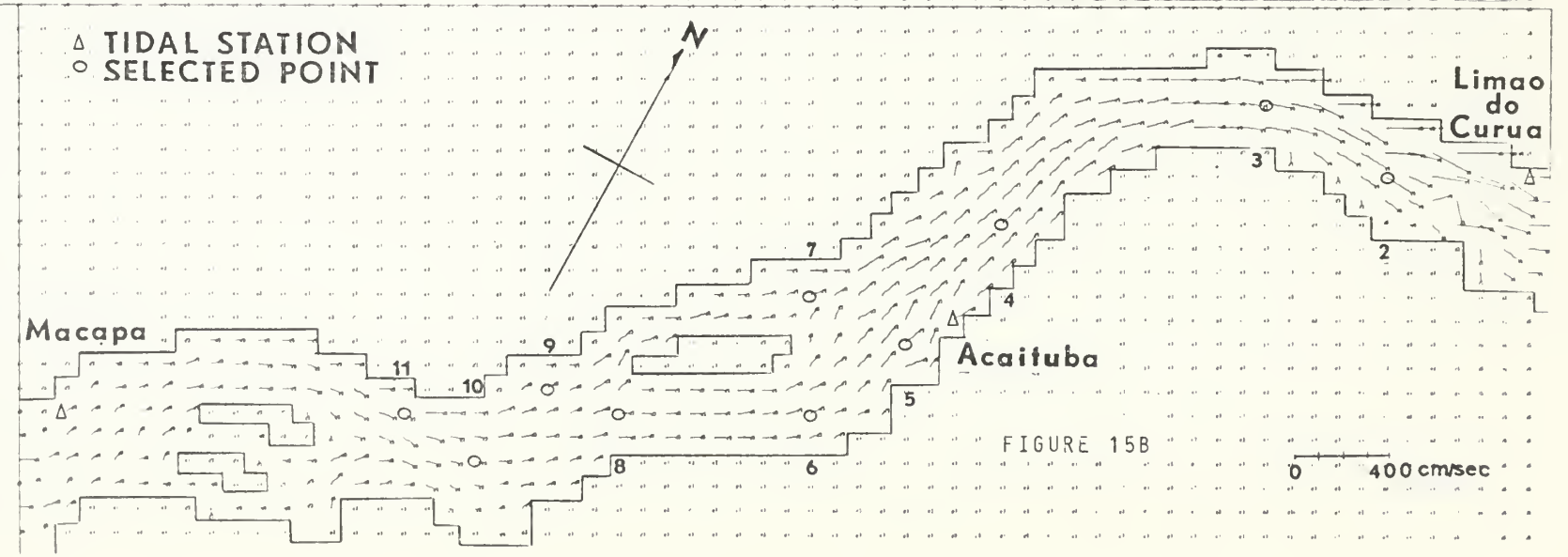


FIGURE 15B

AMAZON SFC CURRENT AFTER 92 HRS

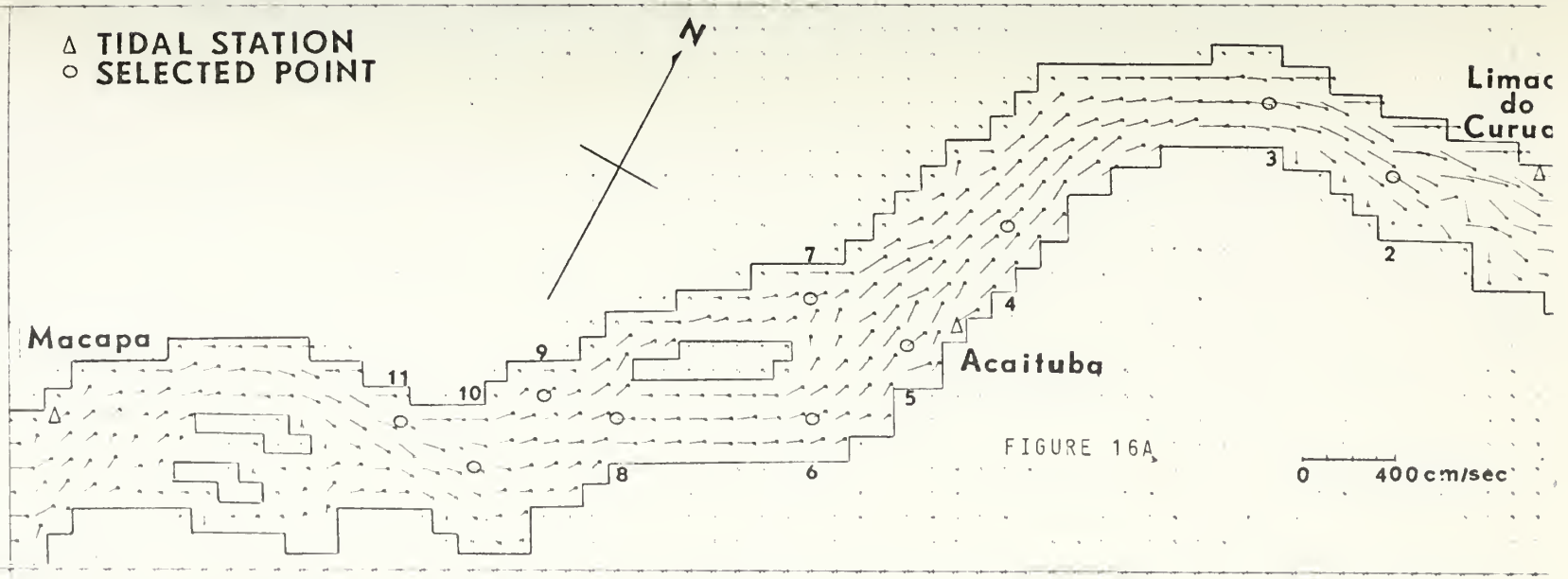


FIGURE 16A

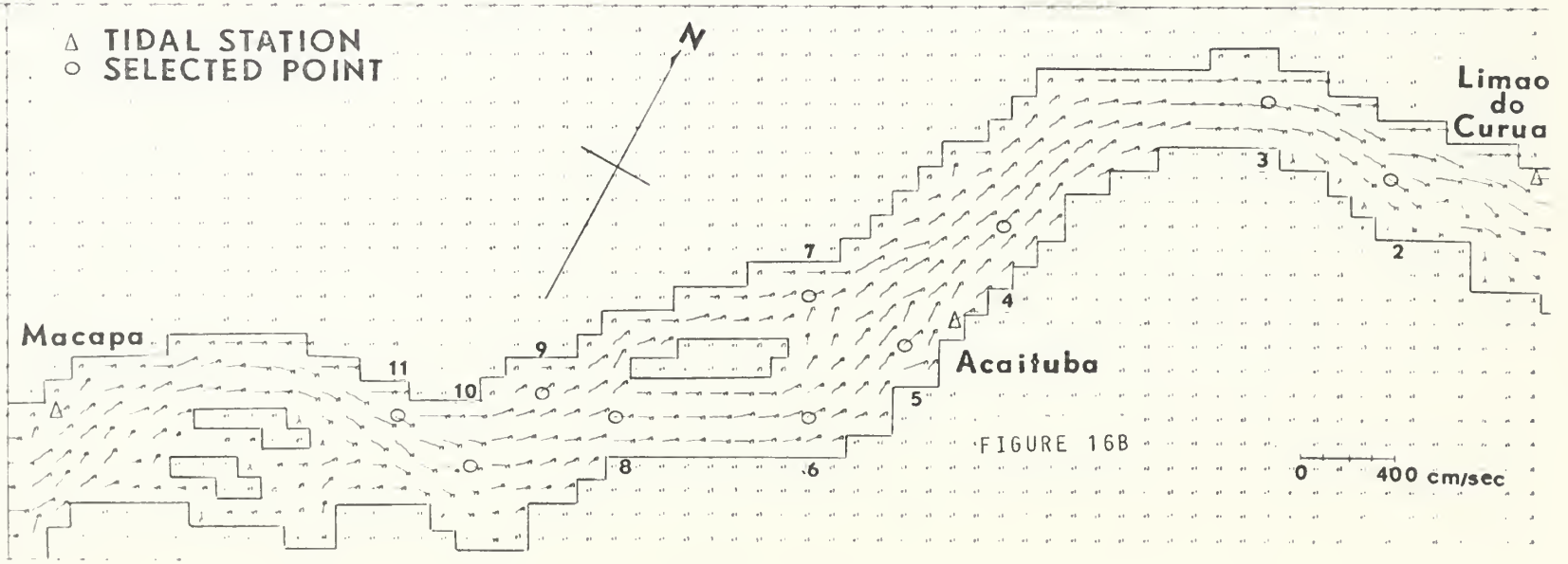


FIGURE 16B

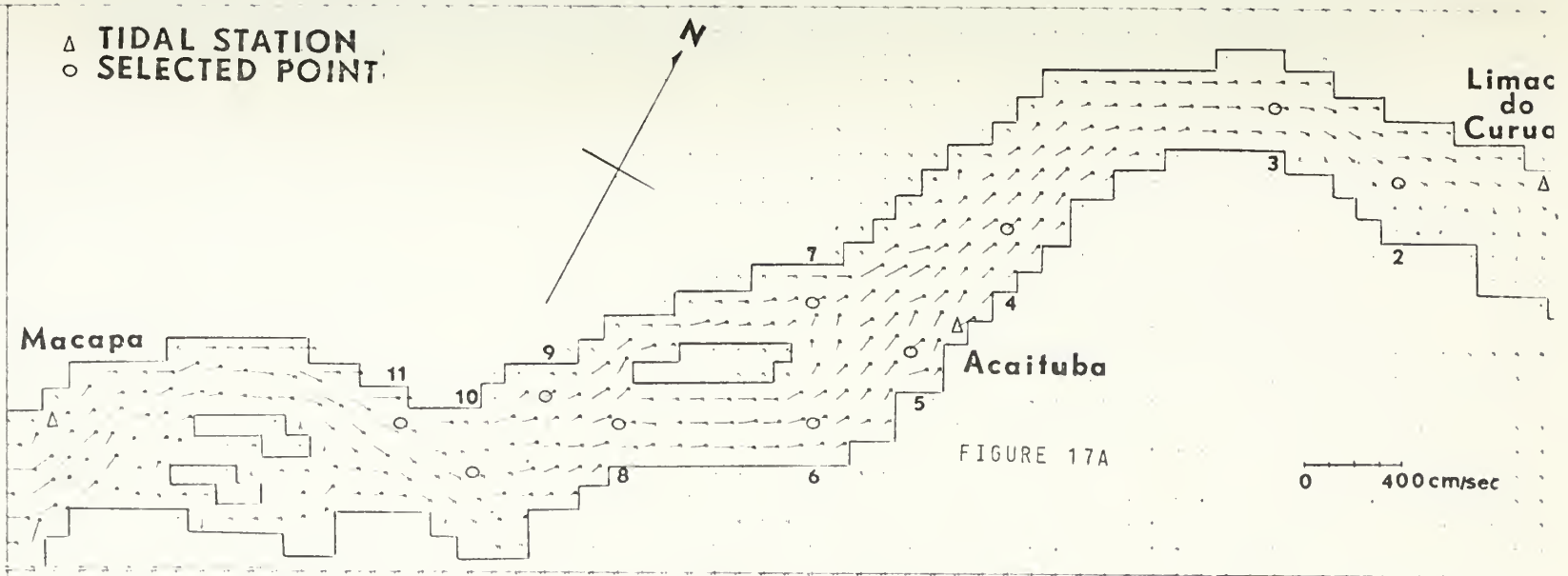


FIGURE 17A

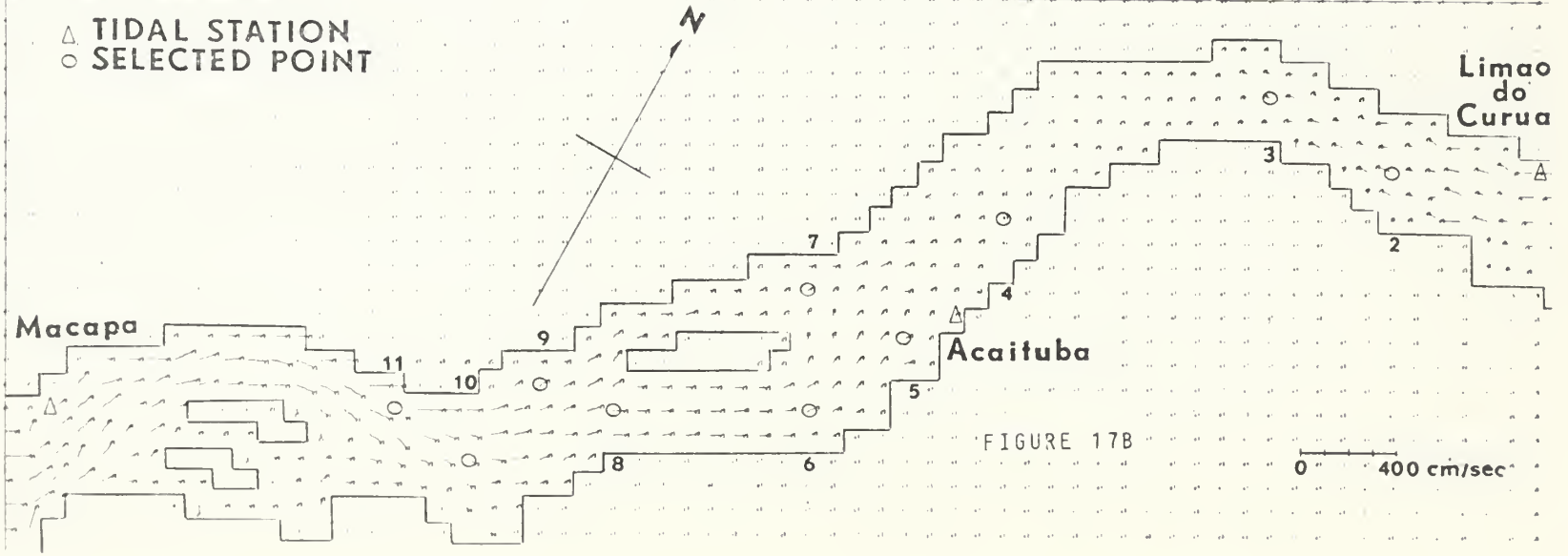


FIGURE 17B

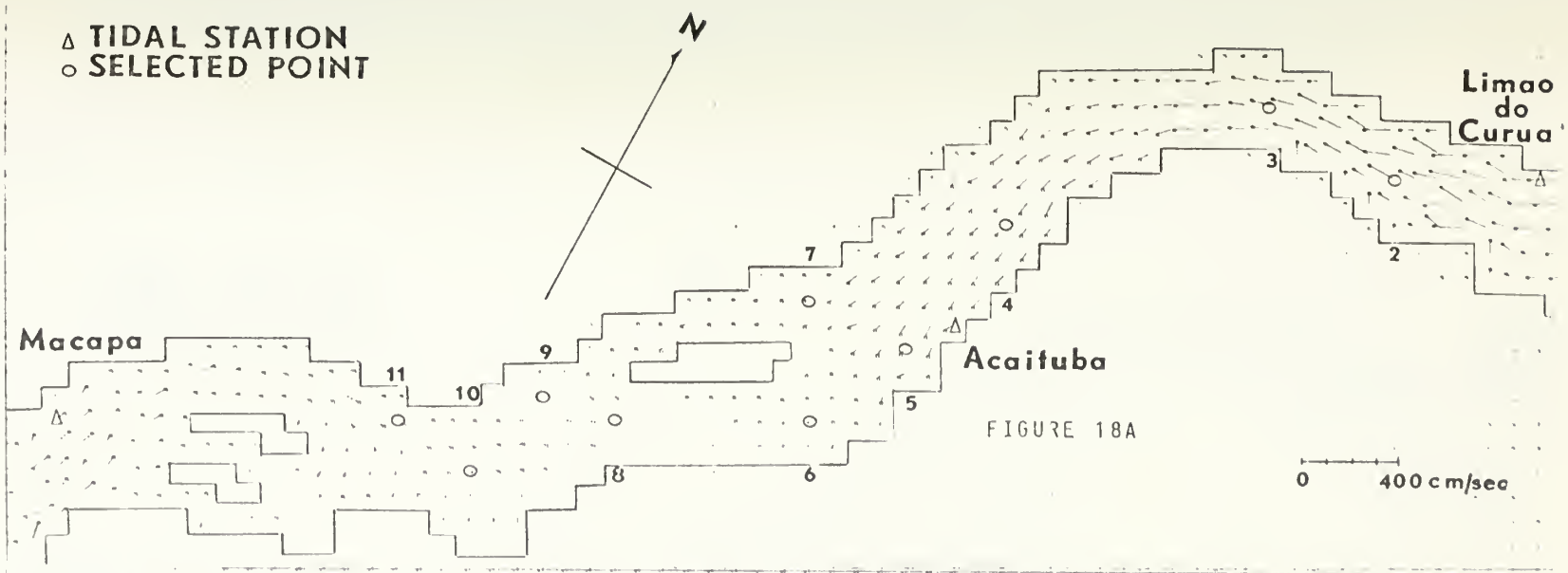


FIGURE 18A

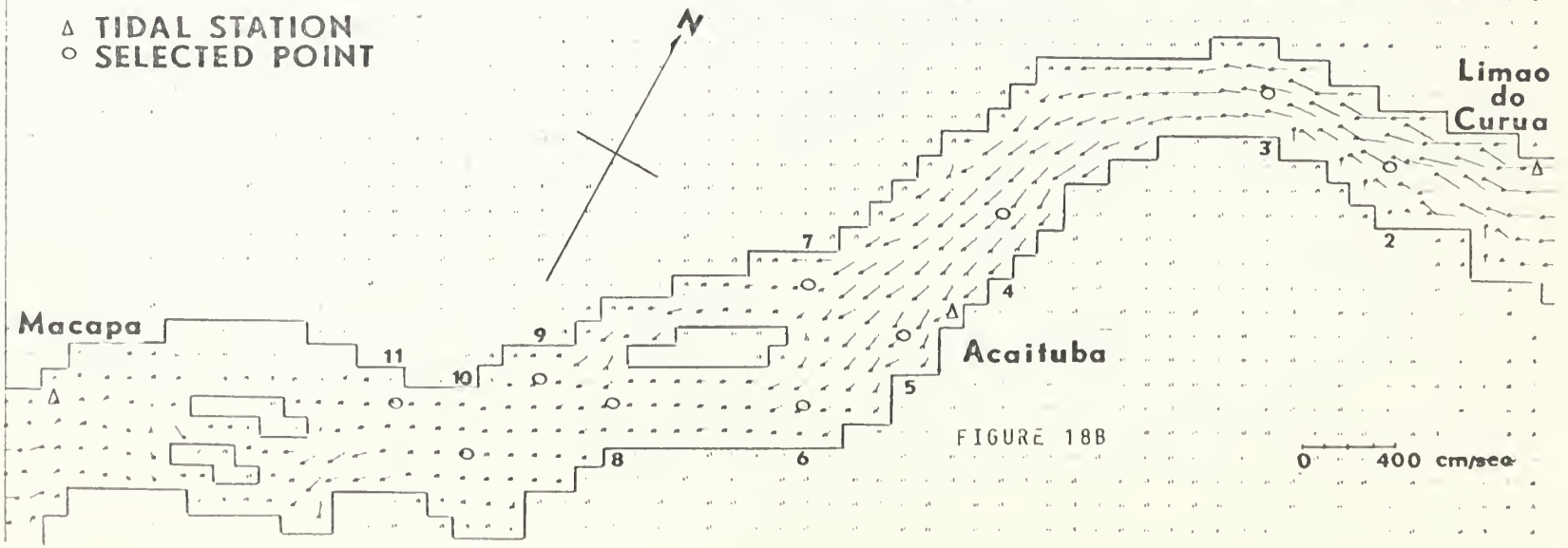


FIGURE 18B

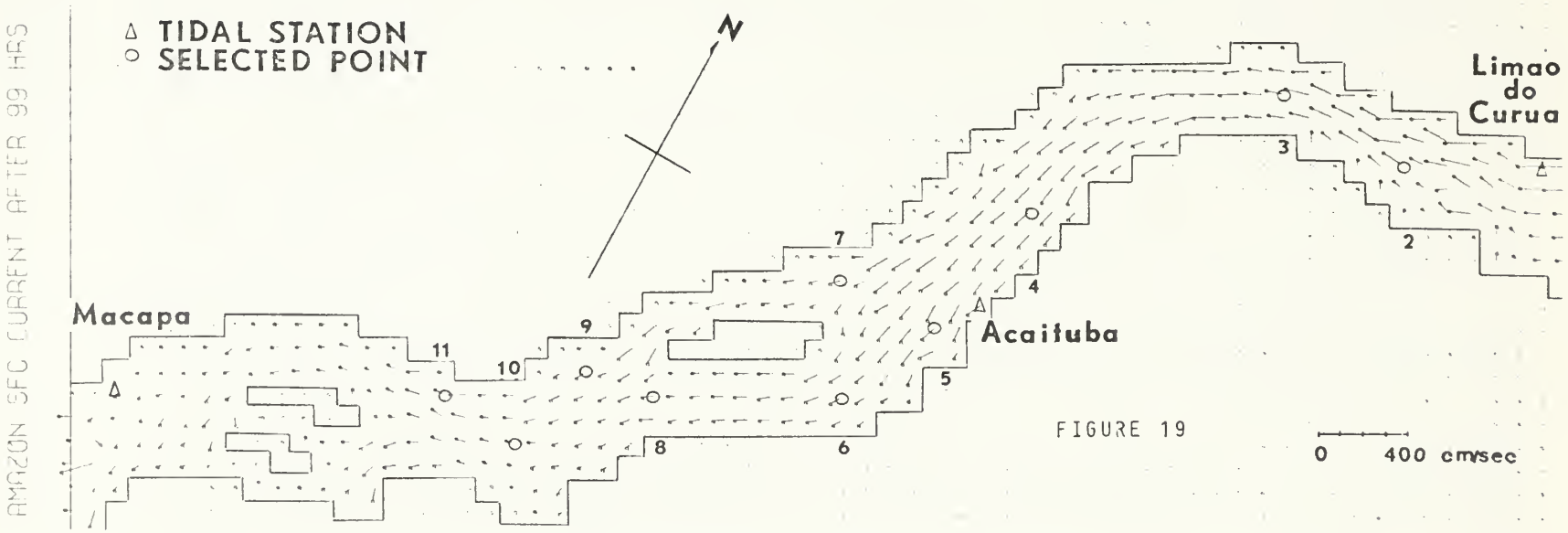

AMAZON SFC CURRENT AFTER 99 HRS
TIDAL STATION
SELECTED POINT
N
Macapa
Acaituba
Limao
do
Curua
11
10
9
8
7
6
5
4
3
2
0
400 cm/sec

FIGURE 19

WATER ELEVATION AND CURRENT VELOCITY RESULTANT MAGNITUDE IN CM/SEC AND DIRECTION IN DEGREES AT SPECIAL POINTS												
TIME (SEC)	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
270000. (75 Hr)												
273600. (76 Hr)												
277200. (77 Hr)												
280800. (78 Hr)												
284400. (79 Hr)												
288000. (80 Hr)												
291600. (81 Hr)												
295200. (82 Hr)												
298800. (83 Hr)												
302400. (84 Hr)												
306000. (85 Hr)												
309600. (86 Hr)												
313200. (87 Hr)												
316800. (88 Hr)												
320400. (89 Hr)												
324000. (90 Hr)												
327600. (91 Hr)												
331200. (92 Hr)												
334800. (93 Hr)												
338400. (94 Hr)												
342000. (95 Hr)												
345600. (96 Hr)												
349200. (97 Hr)												
352800. (98 Hr)												
356400. (99 Hr)												
360000. (100 Hr)												

TABLE III. Computer Output for Water Elevation and Resultant Current Velocity and Direction in 12 Selected Locations

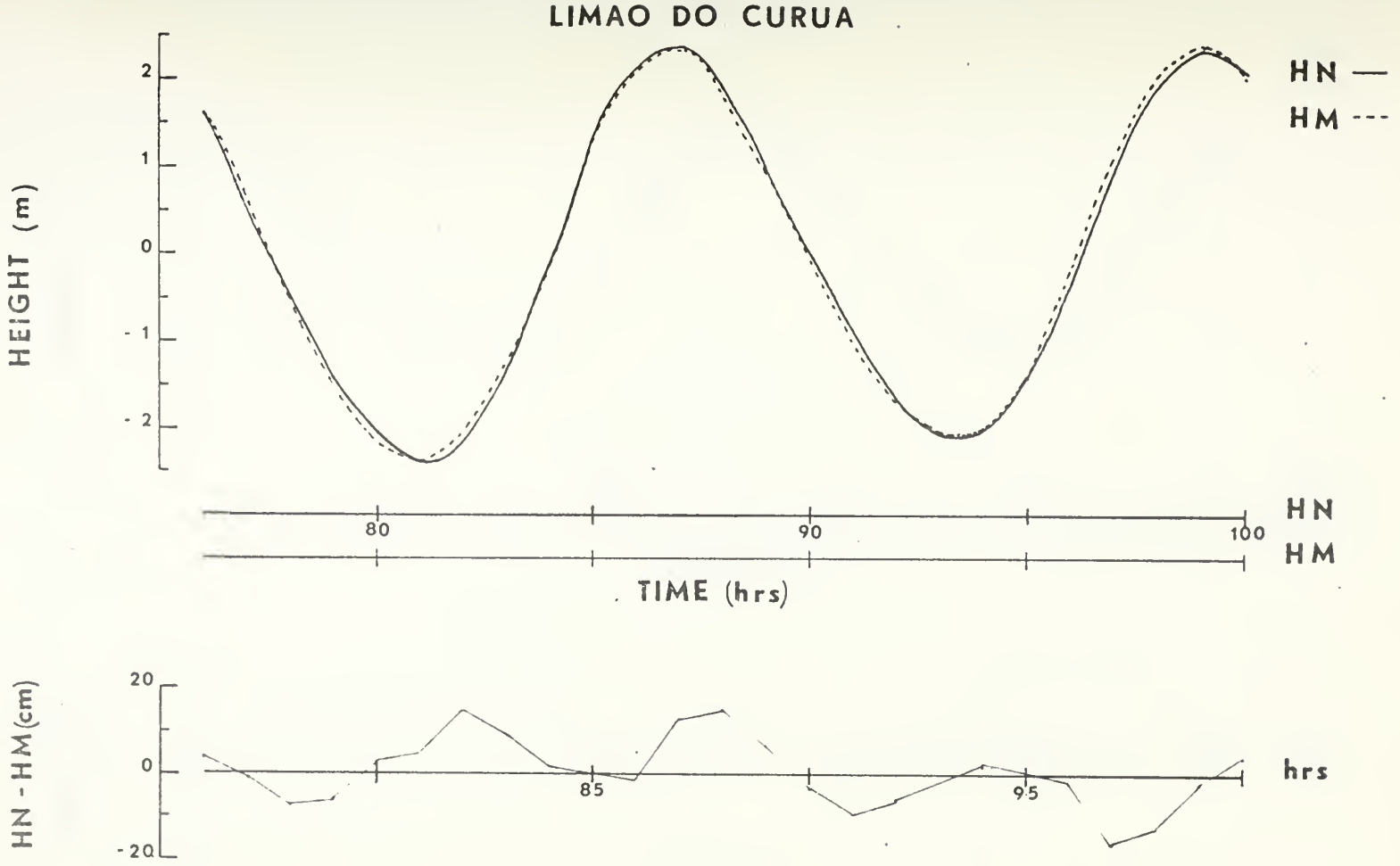

LIMAO DO CURUA
HEIGHT (m)
2
1
0
-1
-2
HN
HM
80
90
100
TIME (hrs)
HN - HM(cm)
20
0
-20
85
95
hrs

FIGURE 20

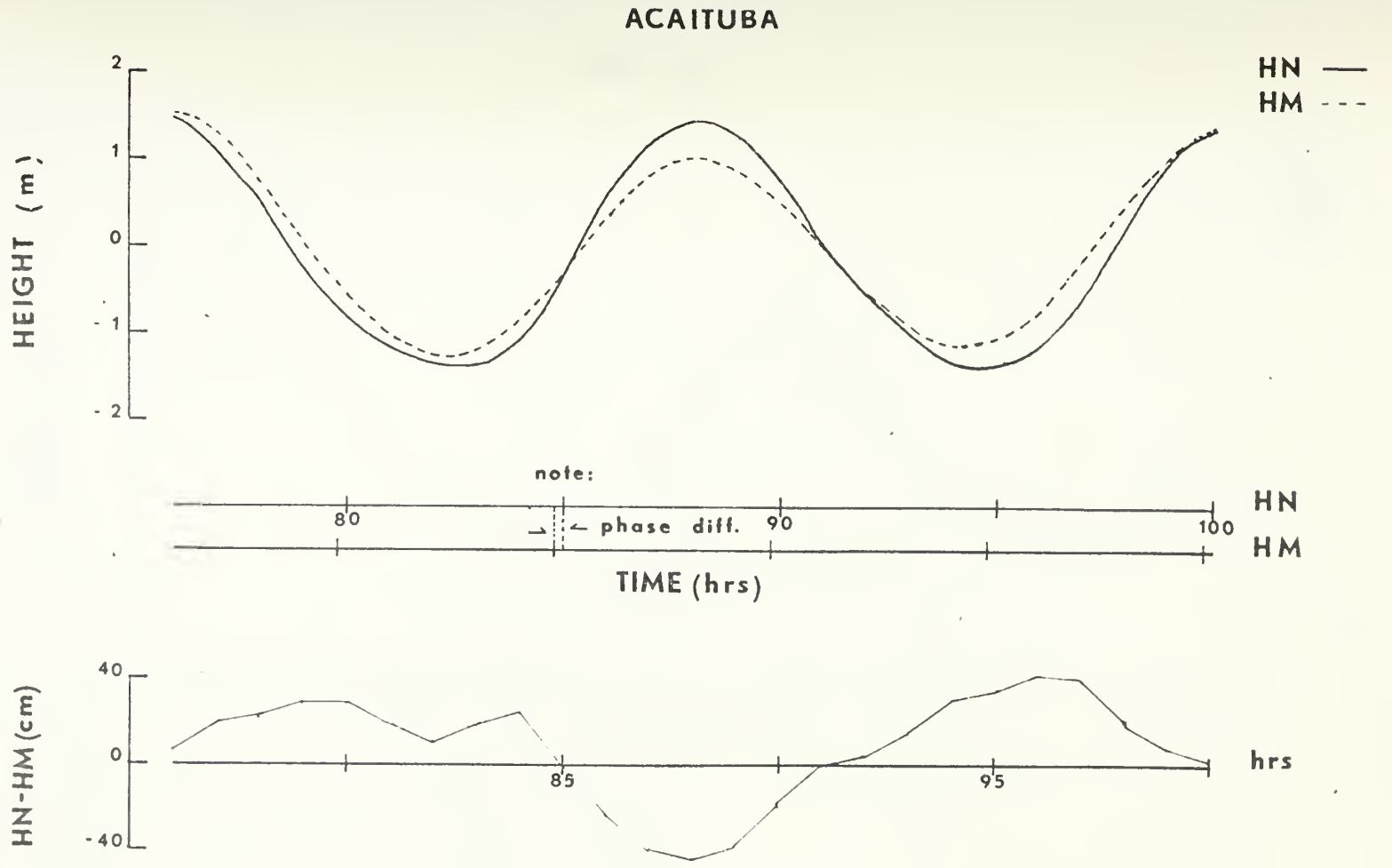

ACAITUBA
HN
HM
HEIGHT (m)
2
1
0
-1
-2
note:
80
phase diff.
90
100
HN
HM
TIME (hrs)
HN-HM (cm)
40
0
-40
85
95
hrs

FIGURE 21

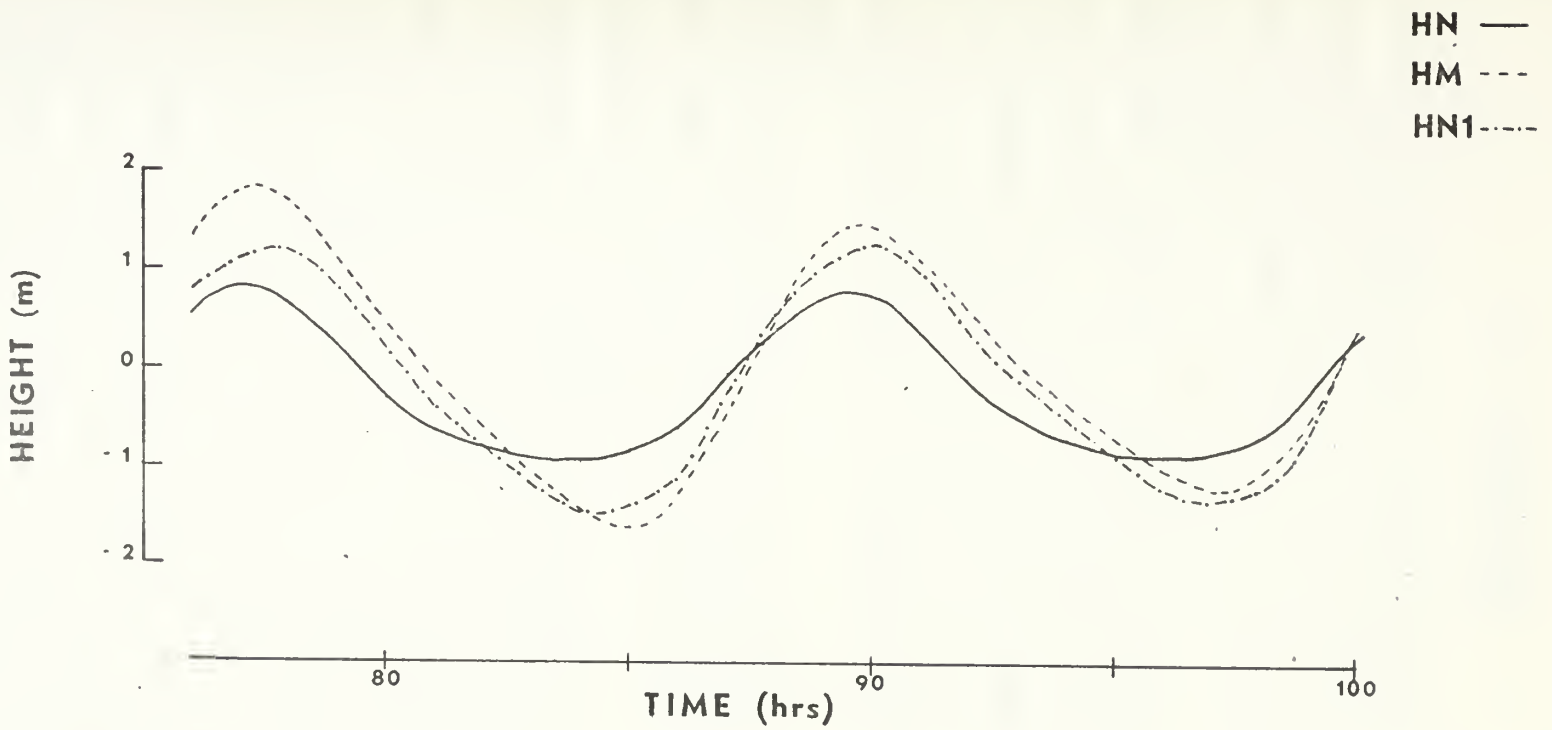


FIGURE 22

IV. DISCUSSION

Before discussing the results obtained upon applying the hydrodynamical-numerical prediction model developed by Hansen to the Amazon's North Channel, it is worthwhile to recall some of its properties or characteristics.

The model represents topographic features in terms of grid points. To obtain a good bathymetric representation a small mesh is required, which may sometimes lead to an extremely large array. It is therefore necessary to compromise between spatial resolution and the amount of computer core memory and time available.

The time resolution is also dependent upon availability of computer time; in general, the smaller the time step the greater the computer time required.

The flow is described by finite difference methods of solution of the equations of motion, which include terms of different orders and degrees, each one describing specific characteristics of the flow. These depend on the external forces applied, location, shape, bathymetry and properties inherent to the fluid. In describing the flow by these equations, it happens that some of the terms become dominant, so that others can be neglected or included in parameters such as K. In addition, Hansen's model neglects the advective non-linear terms, which appears not to cause problems if medium or coarse grids are used but seems to be significant for small grids, as mentioned before.

The finite difference method of solution of the equations of motion makes continuous computation impossible. The calculations are performed by time and spatial increments which can lead to enormous errors if the proper precautions are not taken. One example is that of the eddy diffusivity coefficient, which is affected directly by the grid size and the time step since it is defined in terms of spatial and temporal steps.

The action of viscosity in fluids is of a complicated nature. It may be assumed for the water motion in almost all tidal channels that a complete state of turbulence occurs, so that the flow is practically independent of the exact value of the Reynold's number. Because of the mathematical difficulties involved, the general equations of fluid motion, which include the viscous forces, are not generally solved in applied hydrodynamics. However, the result obtained by completely neglecting the bottom friction is, only under the most favorable circumstances, a satisfactory approximation to the actual fluid motion. Therefore, to determine the flow conditions in a channel, the influence of friction cannot be neglected [4].

To include friction, because the velocity varies in the horizontal as well as in the vertical directions in the cross-sections of the channel, there remains only the possibility of experimentally determining it by tuning the model so that predicted values match as closely as possible the observations.

In tidal channels and inland rivers, the river beds are usually irregular and form hydraulically rough surfaces, turbulence being generated by the irregularities of the bottom.

At the bottom the velocity is zero and increases in the vertical direction until it reaches a maximum value at some distance from the free surface. From this point to the surface the velocities decrease slightly. Observations in very wide channels have shown that the sides of the channel have practically no influence on the velocity distribution in the central region [4].

In engineering and practical problems the determination of the mean velocity in a cross-section is usually sufficient, thus making it necessary to have a relationship between the mean velocity and the frictional forces.

Hansen's model assumes that the bottom stress is directly dependent on U and V but only indirectly on X and t, and the same constant friction coefficient is used in all computations (for this case r = 0.0029).

Finally, the setting of the boundaries and the representation of the coast line and margins is also a matter of personal judgement, and because of this, often the representation of the real boundaries along the grid-points is somewhat difficult and may be questionable.

For our particular case, some facts have contributed to make adequate conclusions impossible. First, the river discharge is inputed as a permanent flow using an estimated value, because at the present time there are no available measurements of the discharge in the Amazon's North Channel. The distribution of the mean velocities in the cross-section was made at only five grid-points which received relatively large values, clearly affecting the resolution.

Second, there is insufficient adequate current measurements to provide a better adjustment of the predicted current velocities, either for the improvement of the estimated river discharge, neither for posterior verifications.

Third, the only tidal station in the middle portion of the Channel, ACAITUBA, had its constituents determined in a very short period of time, and the harmonic prediction for that station, using only few constituents, certainly is not the best. Furthermore, as mentioned before, this station is located about 2 km from the closest grid-point, which in turn is located in much deeper water.

In spite of these facts the model produced numerical results that, if not optimal, are at least acceptable.

The tides predicted at the northern station, LIMAO DO CURUA, agreed with the harmonic prediction within 4% of the tidal range and no phase lag is observed. The maximum difference for the station at ACAITUBA is about 12% of the tidal range, and a phase lag of about 20 minutes is observed, but both may be attributed to the fact that the actual station is over shallower water than it is represented in the grid-point and to the distance from the grid-point to it.

At MACAPA, however, the results are unsatisfactory. This can be, at least partially, attributed to the fact that the grid size is too coarse to describe correctly the bottom topography and the cross-sections in the southern 18 km of the Channel, both very irregular. In fact, smoothing the large gradients between the depths at U- and V- grid-points of same

coordinate designation by making them shallower resulted in a better curve, as is illustrated in Fig. 22. No further improvement was tried because, due to the actual mesh size, the new "false-bottom" would not be realistic, and the procedure was abandoned. A similar situation is reported by Ramming [17] when modelling the Eider River in Germany: the first attempts to reproduce the tides in areas of very irregular cross-sections and depths were not satisfactory, in particular with regard to the steep flood part of the tidal curve. Differences of about 60 cm were recorded in a 3.8 m tidal range. Representing the cross-section by a fine structure of depth distribution, i.e., using a finer grid, led to results in which the maximum deviation was less than 10% of the tidal range and later improvements reduced this deviation to less than 1% of the tidal range [17].

The prediction of currents seems reasonable. At least at the four points where our current predictions were compared to actual observations made by the Brazilian Navy, in identical conditions of river stage, the results are quite satisfactory.

V. SUMMARY

The hydrodynamical-numerical prediction model developed by W. Hansen was applied to the North Channel of the Amazon River for prediction of tides and currents.

The tides predicted by the model agreed, in the worse case, to within 12% of the tidal variations at two stations, but the results at a third location weren't satisfactory. This is attributed to the fact that the irregular shape of the channel in the vicinity of this station was not adequately represented by the grid. Improvement in the results was obtained by smoothing the bottom at the U- and V- grid-points in order to decrease the gradients existing between these points, but no further adjustments were tried because they would be not realistic with the mesh size used. The currents predicted by the model appear to be satisfactorily reproduced, but more measurements are required to allow further conclusions.

It is the intention of the author to continue the investigations in this field to achieve improved results, both by decreasing the mesh dimensions and by using new measurements to be obtained in the near future. Continuation of the study will also be in the form of a two-layer HN-model which the author is preparing for the Amazon Estuary, for which more data and information are available.

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   HANSEN'S HYDRODYNAMICAL NUMERICAL PREDICTION MODEL APPLIED TO
              THE NORTH CHANNEL OF THE AMAZON RIVER
   LTCDR LUIZ ANTONIO DE CARVALHO FERRAZ - BRAZILIAN NAVY
   NOTE: PLOTTING SUBROUTINES NOT INCLUDED IN THIS PROGRAM
PROGRAM 'NORTH-CHANNEL - AMAZON RIVER', MOUTH TO MACAPA
LIST OF PARAMETERS USED AND THEIR SIGNIFICANCE
A(I)      = WIND FIELD CHARACTERISTICS
AH(I,J)   = AMPLITUDE OF TIDAL CONST. AT INDIVIDUAL INPUT
            POINTS
AL(I)     = SPEED OF TIDAL CONSTITUENTS
AINC(I)   = INTERMEDIATE PARAMETER IN INTERP. OF TIDES
ALPHA     = SMOOTHING PARAMETER
ANG(N,M)= CURRENT DIRECTION
ARG(I,J)= ARGUMENT OF TIDAL CONSTITUENT
AUS       = AUSTAUSCH COEFFICIENT
A1 TO A5= INTERMEDIATE PARAMETERS
B(I)      = AMPLITUDES OF SECOND SET OF TIDAL CONSTITUENTS
BETA      = 1 - ALPHA
B1 TO B5= INTERMEDIATE PARAMETERS
C         = DRAG COEFFICIENT
CAINC     = INTERMEDIATE PARAMETER IN INTERPOLATION OF TIDE
CAINCU    = INTERMEDIATE PARAMETER IN INTERPOLATION OF TIDE
CAPA(I,J) G OR K OF FIRST SET OF TIDAL CONST.
CAPAP(I,J)G OR K OF TIDAL CONST.AT INDIVI.INPUT POINTO
CAPAB(I)  G OR K OF SECOND SET OF TIDAL CONST.
CNCU      = INTERMEDIATE PARAMETER IN INTERPOLATION OF TIDE
CW        = A COUNTER
C1        = WIND INDICATOR
C3        = INTERMEDIATE PARAMETER
DL        = HALF GRID SIZE
DT        = HALF TIME STEP
H(I)      = AMPLITUDES OF FIRST SET OF TIDAL CONSTITUENTS
HGU(N,M)= ACTUAL DEPTHS AT U POINTS
HGV(N,M)= ACTUAL DEPTHS AT V POINTS
HTU(N,M)= WATER DEPTHS AT U POINTS
HTV(N,M)= WATER DEPTHS AT V POINTS
HTZ(N,M)= SYMBOLIC WATER-LAND DEPTHS AT Z POINTS
I,J,K,L   = A COUNTER
IU        = NUMBER OF WIND FIELDS
IUE       = TWICE NUMBER OF WIND FIELDS
JA        = INITIATION INDICATOR
JA=0      = COMPUTATIONS INITIALIZED AT ZERO FIELDS
JA=1      = COMPUTATIONS INITIALIZED FROM PREVIOUS VALUES
KI        = TIDE INPUT INDICATOR
KKE       = NUMBER OF WIND FIELD CHARACTERISTICS
KO        = NUMBER OF POINTS AT FIRST OPEN BOUNDARY
LA        = NUMBER OF POINTS AT SECOND OPEN BOUNDARY
LE,LI,LU= INDICATORS FOR REST CURRENT,DIFFUSION-TRANSPORT
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```
LE=0     = NO REST COMPUTATION
LE=1     = REST COMPUTATION
LI=0     = NO DIFFUSION COMPUTATION
LI=1     = DIFFUSION  COMPUTATION
LU=0     = PERMANENT CURRENT NOT INPUTED
LU=1     = PERMANENT CURRENT INPUT
LUP      = INDICATOR FOR SPECIAL POLTTING PRO&RAM
LUP=0    = NO PLOTTING
LUP=1    = PLOTTING REQUIRING ADDITIONAL TAPE
LUN      = INDICATOR FOR SIMPLIFIED DEPTH INPUT
LUN=0    = DEPTHS AT U AND V POINTS DIFFERENT
LUN=1    = DEPTHS AT U AND V POINTS EQUAL
M,N      = GRID INDEXES
ME,NE    = DELIMETERS OF GRID SIZE
MEH,NEH  = ME-1,NE-1
MG,MK,ML= M COORDINATES OF INPUT POINTS AT SEC,FIRST BDRY
          AND INPUT OF PERMANENT CURRENTS
MU,NU    = WIND FIELD DELIMETERS
MUM,NON  = COUNTER
MZ,NZ    = M,N COORDINATES OF SPECIAL POINTS OUTPUT
M1,M2    = INDEXES
NG,NK,NL= N COORDINATES OF INPUT POINTS AT SEC,FIRST BDRY
          AND INPUT OF PERMANENT CURRENTS
NURU     = NUMBER OF SPECIAL OUTPUT POINTS
N1,N2    = INDEXES
PERU(I)  = U CONPONENT OF PERMANENT CURRENT
PERV(I)  = V COMPONENT OF PERMANENT CURRENT
PREC(I)  = INTERMEDIATE FOR INTERPOL. OF TIDAL INPUT
R        = FRICTION  COEFFICIENT
RAD(N,M)= CURRENT SPEED (RESULTANT)
RBETA    = GEOSTROPHIC WIND COEFFICIENT
ROL      = AIR DENSITY
ROOT     = INTERMEDIATE
SI,TW    = TIME WHEN WIND STOPS,STARTS
T        = TIME COUNTER
TE       = LENGHT OF COMPUTATION
TIC,T2   = COUNTER
TIL      = TILT OF GRID WITH RESPECT TO TRUE NORTH
TI       = TIME INTERVAL BETWEEN PRINTOUTS
U(N,M)   = U COMPONENT OF CURRENT
UPB(N,M)= INTERMEDIATE FOR SMOOTHING AND AVERAGING
V(N,M)   = V COMPONENT OF CURRENT
VPB(N,M)= INTERMEDIATE FOR SMOOTHING AND AVERAGING
VRI,VUP  = INTERMEDIATE FOR AVERAGING
VALE,VALO,VARI,VAUP  INTERMEDIATES FOR SMOOTHING
VLE,VLL,VLO,VLR,VUL  INTERMEDIATES FOR AVERAGING
VI       = NAMES OF SPECIAL OUTPUT POINTS
V2 TO V4= INTERMEDIATES FOR OUTPUT AT SPECIAL POINTS
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      XK(N,M) = U COMPONENT OF WIND CURRENT
      YK(N,M) = V COMPONENT OF WIND CURRENT
      Z(N,M)  = WATER LEVEL

MAIN PROGRAM                                                                    AMZ   10
       COMMON HTZ,HTU,HTV,Z,U,V,US,VS,RAD,ANG,XK,YK,NU,MU,NK,MK,AH,CAPAP,       AMZ   20
      1PREC,ARG,PERU,PERV,NL,ML,NZ,MZ,V1,UPB,VPB,S,A,V2,V3 V4,HGU,HGV,H,       AMZ   30
      2B,AL,CAPA,CAPB,AINC,CAINC,NG,MG,TIT,AUS,TAR,OTC,T1,T2,T4,TE,TW,A1,      AMZ   40
      3A2,A3,A4,DT,BETA,ALPHA,F,R,DL,G,C,C3,NE,ME,NEH,MEH,JA,IUE,KKE,NURU      AMZ   50
      4,SI,T,RBETA,CI,SIGMA,ROL,A5,RU,RV,KO,LI,LE,LU,KI,LOP,TRB,TRE,TIC,       AMZ   60
      5LUN,LA,TIL,LIV,LEET,POSN,POSM,DRI,STV,ETV,TINCV,STH,ETC,TINCH,CNCU      AMZ   70
      6,CAINCU                                                                  AMZ   80
       DIMENSION HTZ(24,65),HTU(24,65),HTV(24,65),Z(24,65),U(24,65),V(24,       AMZ   90
      165),US(24,65),VS(24,65),RAD(24,65),ANG(24,65),XK(24,65),YK(24,65),       AMZ  100
      2NU(6),MU(6),NK(10),MK(10),AH(7,10),CAPAP(7,10),PREC(7,10),ARG(7,10       AMZ  110
      3),PERU(5),PERV(5),NL(5),ML(5),NZ(20),MZ(20),V1(20),UPB(24,65),           AMZ  120
      4VPB(24,65),S(24,65),A(3),V2(20),V3(20),V4(20),HGU(24,65),HGV(24,65       AMZ  130
      5),H(7),B(7),AL(7),CAPA(7),CAPB(7),AINC(7),CAINC(7),NG(5),MG(5),          AMZ  140
      6TIT(4),AUS(4),TAR(4),OTC(4)                                              AMZ  150
       DIMENSION MAP(24,65),TITLE(8),UPLOT(24,65),VPLOT(24,65)                  AMZ  160
CONTROLL PROGRAM                                                                AMZ  170
ZEROING OF ARRAYS                                                               AMZ  180
       DO 1000  N=1,24                                                          AMZ  190
       DO 1000  M=1,65                                                          AMZ  200
       HTZ(N,M) = 0.0                                                           AMZ  210
       HTU(N,M) = 0.0                                                           AMZ  220
       HTV(N,M) = 0.0                                                           AMZ  230
       UPB(N,M) = 0.0                                                           AMZ  240
       VPB(N,M) = 0.0                                                           AMZ  250
       HGU(N,M) = 0.0                                                           AMZ  260
       HGV(N,M) = 0.0                                                           AMZ  270
       RAD(N,M) = 0.0                                                           AMZ  280
       ANG(N,M) = 0.0                                                           AMZ  290
       US (N,M) = 0.0                                                           AMZ  300
       VS (N,M) = 0.0                                                           AMZ  310
       XK (N,M) = 0.0                                                           AMZ  320
       YK (N,M) = 0.0                                                           AMZ  330
       Z  (N,M) = 0.0                                                           AMZ  340
       U  (N,M) = 0.0                                                           AMZ  350
       V  (N,M) = 0.0                                                           AMZ  360
       S  (N,M) = 0.0                                                           AMZ  370
 1000 CONTINUE                                                                  AMZ  380
    4 REWIND 2                                                                  AMZ  390
    5 CALL JOB1                                                                 AMZ  400
 1007 CONTINUE                                                                  AMZ  410
    6 CALL JOB3                                                                 AMZ  420
 1009 CONTINUE                                                                  AMZ  430
 1010 IF(LOP) 7,7,1011                                                          AMZ  440
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1011 IF(T-TE) 7,240,240                                                    AMZ 450
 240 IF(LOP)1016,1016,241                                                  AMZ 460
 241 IF(LOP-5)1013,1016,1016                                               AMZ 470
   7 T2=T2+T1                                                              AMZ 480
   9 CALL JOB2                                                             AMZ 490
   8 T=T+A1                                                                AMZ 500
  10 IF(T-TE)11,1012,1012                                                  AMZ 510
  11 IF(ABS (T-T2)-A1/2.)6,6,12                                            AMZ 520
  12 GO TO 8                                                               AMZ 530
1012 IF(LOP)13,13,1013                                                     AMZ 540
1013 LOP=5                                                                 AMZ 550
  13 CALL JOB3                                                             AMZ 560
1014 IF(LOP)1016,1016,1015                                                 AMZ 570
1015 CONTINUE                                                              AMZ 580
1016 END FILE 2                                                            AMZ 590
  14 REWIND 2                                                              AMZ 600
  15 CALL JOB5                                                             AMZ 610
1017 IF(LOP)16,16,245                                                      AMZ 620
 245 CONTINUE                                                              AMZ 630
1018 CONTINUE                                                              AMZ 640
  16 STOP                                                                  AMZ 650
      END                                                                  AMZ 660
      SUBROUTINE JOB1                                                      AMZ 670
      COMMON HTZ,HTU,HTV,Z,U,V,US,VS,RAD,ANG,XK,YK,NU,MU,NK,MK,AH,CAPAP,   AMZ 680
     1PREC,ARG,PERU,PERV,NL,ML,NZ,MZ,V1,UPB,VPB,S,A,V2,V3 V4,HGU,HGV,H,    AMZ 690
     2B,AL,CAPA,CAPB,AINC,CAINC,NG,MG,TIT,AUS,TAR,OTC,T1,T2,T4,TE,TW,A1,   AMZ 700
     3A2,A3,A4,DT,BETA,ALPHA,F,R,DL,G,C,C3,NE,ME,NEH,MEH,JA,IUE,KKE,NURU   AMZ 710
     4,SI,T,RBETA,C1,SIGMA,ROL,A5,RU,RV,KU,LI,LE,LU,KI,LOP,TRB,TRE,TIC,    AMZ 720
     5LUN,LA,TIL,LIV,LEET,POSN,POSM,DRI,STV,ETV,TINCV,STH,ETC,TINCH,CNCU    AMZ 730
     6,CAINCU                                                              AMZ 740
      DIMENSION HTZ(24,65),HTU(24,65),HTV(24,65),Z(24,65),U(24,65),V(24,   AMZ 750
     165),US(24,65),VS(24,65),RAD(24,65),ANG(24,65),XK(24,65),YK(24,65),   AMZ 760
     2NU(6),MU(6),NK(10),MK(10),AH(7,10),CAPAP(7,10),PREC(7,10),ARG(7,10   AMZ 770
     3),PERU(5),PERV(5),NL(5),ML(5),NZ(20),MZ(20),V1(20),UPB(24,65),        AMZ 780
     4VPB(24,65),S(24,65),A(3),V2(20),V3(20),V4(20),HGU(24,65),HGV(24,65    AMZ 790
     5),H(7),B(7),AL(7),CAPA(7),CAPB(7),AINC(7),CAINC(7),NG(5),MG(5),       AMZ 800
     6TIT(4),AUS(4),TAR(4),OTC(4)                                          AMZ 810
      DIMENSION MAP(24,65),TITLE(8),UPLOT(24,65),VPLOT(24,65)              AMZ 820
READING OF VALUES AND INITIATION                                           AMZ 830
 3838 FORMAT(24F3.0)                                                       AMZ 840
   38 FORMAT(12F6.0)                                                       AMZ 850
   29 CONTINUE                                                             AMZ 860
   30 FORMAT(24I3)                                                         AMZ 870
   31 FORMAT(9F8.3)                                                        AMZ 880
   32 FORMAT(9F8.0)                                                        AMZ 890
   33 FORMAT(6E12.4)                                                       AMZ 900
   34 FORMAT(15(1X,A4))                                                    AMZ 910
   35 FORMAT(9F8.2)                                                        AMZ 920
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   36 FORMAT(14F5.1)                                                    AMZ 930
   37 FORMAT (7F10.7)                                                   AMZ 940
   55 FORMAT(F10.2)                                                     AMZ 950
READING OF INPUT DATA                                                  AMZ 960
      READ 30,JA,NE,ME,KO,IUE,KKE,NURU,KI,LE,LU,LI,LOP                 AMZ 970
     1,LA,LUN,LIV,LEET                                                 AMZ 980
      READ 31,G,ALPHA,RBETA,C1,TIL                                     AMZ 990
      READ 32,DT,TE,TW,T1,T2,SI,T,TRB,TRE                              AMZ1000
 1006 IF(LEET) 43,43,1008                                              AMZ1010
 1008 READ 32,T4                                                       AMZ1020
   43 READ 33,DL,F,SIGMA,R,ROL,C                                       AMZ1030
      READ 55,AUS(1)                                                   AMZ1040
      READ 30,(NK(I),MK(I),I=  1,KO)                                   AMZ1050
      READ 30,(NZ(I),MZ(I),I=1,NURU)                                   AMZ1060
      READ 30,(NU(I),MU(I),I=1,IUE)                                    AMZ1070
      READ 34,(V1(I),I=1,NURU)                                         AMZ1080
 1030 NLN=1                                                            AMZ1090
 1036 CW = 1.                                                          AMZ1100
 1032 CW=CW+1.                                                         AMZ1110
 1033 NON=KKE+1                                                        AMZ1120
 1034 KKE=KKE+NON-1                                                    AMZ1130
 1037 IF(C1-CW) 49,48,48                                               AMZ1140
   48 READ 35,(A(I),I=NON,KKE)                                         AMZ1150
   49 READ 36,(H(I),I=1,7)                                             AMZ1160
   50 READ 37,(AL(I),I=1,7)                                            AMZ1170
   51 READ 37,(CAPA(I),I=1,7)                                          AMZ1180
   52 READ 3838,((HTZ(N,M),N=1,NE),M=1,ME)                             AMZ1190
      DO 9966 N=13,17                                                  AMZ1200
      HTZ(N,2)=-2.                                                     AMZ1210
 9966 HTZ(N,1)=0.                                                      AMZ1220
      HTZ(12,1) =0.                                                    AMZ1230
 1022 IF(LUN) 53,53,54                                                 AMZ1240
   53 READ 38,((HTU(N,M),N=1,NE),M=1,ME)                               AMZ1250
   54 READ 38,((HTV(N,M),N=1,NE),M=1,ME)                               AMZ1260
   72 READ 30,(NL(I),ML(I),I=1,LU)                                     AMZ1270
   73 READ 36,(PERU(I),I=1,LU)                                         AMZ1280
   74 READ 36,(PERV(I),I=1,LU)                                         AMZ1290
 1005 CONTINUE                                                         AMZ1300
SETTING OF SOME COMPUTATIONAL PARAMETERS                               AMZ1310
   60 BETA=(1.-ALPHA)/4.                                               AMZ1320
   61 A1=2.*DT                                                         AMZ1330
      A2= F * A1                                                       AMZ1340
   63 A3=R*A1                                                          AMZ1350
   64 A4=DT/DL                                                         AMZ1360
   65 A5=G*A4                                                          AMZ1370
   66 C3=C*A1*10000.                                                   AMZ1380
   67 NEH=NE-1                                                         AMZ1390
   68 MEH=ME-1                                                         AMZ1400
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```
 1052 KKE = (IUE/2) * 3                                                                                    AMZ1410
INITIALIZATION OF THE ARRAYS WITH ZERO OR A SMALL VALUE                                                    AMZ1420
   75 DO 100 N=1,NE                                                                                        AMZ1430
   76 DO 100 M=1,ME                                                                                        AMZ1440
   77 IF(HTZ(N,M)) 78,78,80                                                                                AMZ1450
   78 Z(N,M)=0.                                                                                            AMZ1460
      VPB(N,M)=0.                                                                                          AMZ1470
   79 GO TO 81                                                                                             AMZ1480
   80 Z(N,M)=0.2                                                                                           AMZ1490
      VPB(N,M)=0.2                                                                                         AMZ1500
   81 IF(HTU(N,M)) 82,82,84                                                                                AMZ1510
   82 U(N,M)=0.                                                                                            AMZ1520
      UPB(N,M)=0.                                                                                          AMZ1530
   83 GO TO 85                                                                                             AMZ1540
   84 U(N,M)=0.2                                                                                           AMZ1550
      UPB(N,M)=0.2                                                                                         AMZ1560
      IF(4000.-HTU(N,M)) 2085,2085,85                                                                      AMZ1570
 2085 HTU(N,M) = 4000.                                                                                     AMZ1580
   85 IF(HTV(N,M))86,86,88                                                                                 AMZ1590
   86 V(N,M)=0.                                                                                            AMZ1600
      VPB(N,M)=0.                                                                                          AMZ1610
   87 GO TO 95                                                                                             AMZ1620
   88 V(N,M)=0.2                                                                                           AMZ1630
      VPB(N,M)=0.2                                                                                         AMZ1640
   95 XK(N,M)=0.                                                                                           AMZ1650
   96 YK(N,M)=0.                                                                                           AMZ1660
      S(N,M)=0.                                                                                            AMZ1670
      US(N,M) = 0.                                                                                         AMZ1680
      VS(N,M) = 0.                                                                                         AMZ1690
      IF(HTV(N,M).LE.0) GO TO    100                                                                       AMZ1700
      IF(4000.-HTV(N,M)) 2096,2096,100                                                                     AMZ1710
 2096 HTV(N,M) = 4000.                                                                                     AMZ1720
  100 CONTINUE                                                                                             AMZ1730
      DO 4100  N=1,NE                                                                                      AMZ1740
      DO 4100  M=1,ME                                                                                      AMZ1750
      IF(HTU(N,M).LT.100..AND.HTU(N,M).GT.0)  HTU(N,M)=100.                                                AMZ1760
      IF(HTV(N,M).LT.100..AND.HTV(N,M).GT.0)  HTV(N,M)=100.                                                AMZ1770
 4100 CONTINUE                                                                                             AMZ1780
  200 CONTINUE                                                                                             AMZ1790
  120 DO 124 J=1,KO                                                                                        AMZ1800
  121 DO 124 I=1,7                                                                                         AMZ1810
  122 AH(I,J)=H(I)                                                                                         AMZ1820
  123 CAPAP(I,J)=CAPA(I)                                                                                   AMZ1830
  124 CONTINUE                                                                                             AMZ1840
  125 CONTINUE                                                                                             AMZ1850
PRINTING THE INPUT DATA FOR CHECKING PURPOSES                                                              AMZ1860
 1131 PRINT 181,DT,DL                                                                                      AMZ1870
 1132 PRINT 182,F,AUS(1)                                                                                   AMZ1880
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      PRINT 6168,R                                                          AMZ1890
1133  PRINT 183,ALPHA,C1                                                    AMZ1900
1134  PRINT 184,TE,T1,TW,SI                                                 AMZ1910
1115  PRINT 1142,TIL                                                        AMZ1920
1116  PRINT 1143,KI,LE,LU,LI,LOP,LUN,LA,LIV                                 AMZ1930
1120  CONTINUE                                                              AMZ1940
1135  PRINT 185,(NK(I),MK(I),I=1,KO)                                        AMZ1950
1136  PRINT 186,H(1),H(2),H(3),H(4),H(5),H(6),H(7)                          AMZ1960
1137  PRINT 187,AL(1),AL(2),AL(3),AL(4),AL(5),AL(6),AL(7)                   AMZ1970
1138  PRINT 188,CAPA(1),CAPA(2),CAPA(3),CAPA(4),CAPA(5),CAPA(6),CAPA(7)     AMZ1980
1140  MUM = IFIX (C1*3.)                                                    AMZ1990
1139  PRINT 189,(A(I),I=1,MUM)                                              AMZ2000
1124  CONTINUE                                                              AMZ2010
1125  IF(LU)1128,1128,1126                                                  AMZ2020
1126  PRINT 1146,(NL(I),ML(I),I=1,LU)                                       AMZ2030
1127  PRINT 1147, (PERU(I),PERV(I),I=1,LU)                                  AMZ2040
1128  CONTINUE                                                              AMZ2050
 181  FORMAT(5X,19HHALF TIME STEP DT =,F5.0,5H  SEC,29X,20HHALF GRID SIZ    AMZ2060
     1E DL = ,E11.4,4H  CM//)                                               AMZ2070
 182  FORMAT(5X,21HCORIOLIS PARAMETER =,E12.4,5X,16HAUSTAUSCH COEF.=,       AMZ2080
     1E10.2//)                                                              AMZ2090
 183  FORMAT(5X,27HSMOOTHING PARAMETER ALPHA =,F6.3,20X,19HWIND INDICATO    AMZ2100
     1R C1 =,F8.3//)                                                        AMZ2110
 184  FORMAT(5X,16HCOMP. LENGTH ,F8.0,5X,15HOUTPUT INTERV. ,F8.0,5X,15HW    AMZ2120
     1IN  STARTS AT ,F8.0,5X,11HWIND STOPS ,F8.0,6HSECONS,//)               AMZ2130
 185  FORMAT(5X,49H(N,M) COORDINATES OF INPUT POINTS AT THE BOUNDARY ,//     AMZ2140
     15X,5(1H(,I2,1H,,I2,1H),2X)///)                                        AMZ2150
 186  FORMAT(5X,'AMPLITUDES OF TIDE CONST.',5X,7F10.1//)                     AMZ2160
 187  FORMAT(5X,20HSPEDS OF TIDE CONST.,5X,7F10.7,//)                        AMZ2170
 188  FORMAT(5X,21HKAPPAS OF TIDE CONST.,5X,7F10.7,//)                       AMZ2180
 189  FORMAT(5X,25HWIND,INTERV.,SPEED,DIR.  ,9F8.2,//5X,12F8.2,//)          AMZ2190
1142  FORMAT(5X,12HTILT OF GRID,5X,F4.0,//)                                 AMZ2200
1143  FORMAT(5X,3HKI=,I3,3HLE=,I3,3HLU=,I3,3HLI=,I3,4HLOP=,I3,4HLUN=,I3,    AMZ2210
     13HLA=,I3,4HLIV=,I3,//)                                                AMZ2220
1162  FORMAT(///8X,7I8)                                                     AMZ2230
1163  FORMAT(I8,7F8.0)                                                      AMZ2240
1146  FORMAT(5X,24HCOORD.OF PERM.CURR.INPUT,//5X,5(1H(,I2,1H,,I2,1H),2X)    AMZ2250
     1/)                                                                    AMZ2260
1147  FORMAT(5X,26HU AND V COMP.OF PERM.CURR.,/5X,5(1H(,F5.1,1H,,F5.1,1H    AMZ2270
     1),2X)/5X,5(1H(,F5.1,1H,,F5.1,1H),2X)/5X,5(1H(,F5.1,1H,,F5.1,1H),2X    AMZ2280
     2)//)                                                                  AMZ2290
      PRINT 6160,(N,N=1,15)                                                 AMZ2300
      PRINT 6161,(N,(HTZ(N,M),M=1,15),N=1,NE)                               AMZ2310
      PRINT 6162,(N,N=16,30)                                                AMZ2320
      PRINT 6161,(N,(HTZ(N,M),M=16,30),N=1,NE)                              AMZ2330
      PRINT 6162,(N,N=31,45)                                                AMZ2340
      PRINT 6161,(N,(HTZ(N,M),M=31,45),N=1,NE)                              AMZ2350
      PRINT 6162,(N,N=46,60)                                                AMZ2360
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      PRINT 6161,(N,(HTZ(N,M),M=46,60),N=1,NE)                                  AMZ2370
      PRINT 6164,(N,N=61,65)                                                    AMZ2380
      PRINT 6163,(N,(HTZ(N,M),M=61,65),N=1,NE)                                  AMZ2390
      PRINT 6165,(N,N=1,15)                                                     AMZ2400
      PRINT 6161,(N,(HTU(N,M),M=1,15),N=1,NE)                                   AMZ2410
      PRINT 6162,(N,N=16,30)                                                    AMZ2420
      PRINT 6161,(N,(HTU(N,M),M=16,30),N=1,NE)                                  AMZ2430
      PRINT 6162,(N,N=31,45)                                                    AMZ2440
      PRINT 6161,(N,(HTU(N,M),M=31,45),N=1,NE)                                  AMZ2450
      PRINT 6162,(N,N=46,60)                                                    AMZ2460
      PRINT 6161,(N,(HTU(N,M),M=46,60),N=1,NE)                                  AMZ2470
      PRINT 6164,(N,N=61,65)                                                    AMZ2480
      PRINT 6163,(N,(HTU(N,M),M=61,65),N=1,NE)                                  AMZ2490
      PRINT 6165,(N,N=1,15)                                                     AMZ2500
      PRINT 6161,(N,(HTV(N,M),M=1,15),N=1,NE)                                   AMZ2510
      PRINT 6162,(N,N=16,30)                                                    AMZ2520
      PRINT 6161,(N,(HTV(N,M),M=16,30),N=1,NE)                                  AMZ2530
      PRINT 6162,(N,N=31,45)                                                    AMZ2540
      PRINT 6161,(N,(HTV(N,M),M=31,45),N=1,NE)                                  AMZ2550
      PRINT 6162,(N,N=46,60)                                                    AMZ2560
      PRINT 6161,(N,(HTV(N,M),M=46,60),N=1,NE)                                  AMZ2570
      PRINT 6164,(N,N=61,65)                                                    AMZ2580
      PRINT 6163,(N,(HTV(N,M),M=61,65),N=1,NE)                                  AMZ2590
 6160 FORMAT (1X,'SYMBOLIC WATER DEPTH AT THE Z POINTS'//8X,15I8/)              AMZ2600
 6161 FORMAT (I8,15F8.0)                                                        AMZ2610
 6162 FORMAT (///8X,15I8)                                                       AMZ2620
 6163 FORMAT (I8,5F8.0)                                                         AMZ2630
 6164 FORMAT (///8X,5I8)                                                        AMZ2640
 6165 FORMAT (1X,'WATER DEPTH AT THE U POINTS'//8X,15I8)                        AMZ2650
 6166 FORMAT (1X,'WATER DEPTH AT THE V POINTS'//8X,15I8)                        AMZ2660
 6168 FORMAT (2X,'BOTTOM FRICTION COEFFICIENT R=',F9.5//)                       AMZ2670
SETTING  (INITIAL) OF VARIABLE DEPTH                                            AMZ2680
  170 DO 175 N=1,NE                                                             AMZ2690
  171 DO 175 M=1,ME                                                             AMZ2700
  173 HGU(N,M)=HTU(N,M)                                                         AMZ2710
  174 HGV(N,M)=HTV(N,M)                                                         AMZ2720
 1175 CONTINUE                                                                  AMZ2730
  175 CONTINUE                                                                  AMZ2740
      RETURN                                                                    AMZ2750
      END                                                                       AMZ2760
      SUBROUTINE JOB2                                                           AMZ2770
      COMMON HTZ,HTU,HTV,Z,U,V,US,VS,RAD,ANG,XK,YK,NU,MU,NK,MK,AH,CAPAP,        AMZ2780
     1PREC,ARG,PERU,PERV,NL,ML,NZ,MZ,V1,UPB,VPB,S,A,V2,V3 V4,HGU,HGV,H,        AMZ2790
     2B,AL,CAPA,CAPB,AINC,CAINC,NG,MG,TIT,AUS,TAR,OTC,T1,T2,T4,TE,TW,AI,       AMZ2800
     3A2,A3,A4,DT,BETA,ALPHA,F,R,DL,G,C,C3,NE,ME,NEH,MEH,JA,IUE,KKE,NURU       AMZ2810
     4,SI,I,RBETA,C1,SIGMA,ROL,A5,RU,RV,KO,LI,LE,LU,KI,LOP,TRB,TRE,TIC,        AMZ2820
     5LUN,LA,TIL,LIV,LEET,POSN,POSM,DRI,STV,ETV,TINCV,STH,ETC,TINCH,CNCU       AMZ2830
     6,CAINCU                                                                   AMZ2840
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      DIMENSION HTZ(24,65),HTU(24,65),HTV(24,65),Z(24,65),U(24,65),V(24,  AMZ2850
     165),US(24,65),VS(24,65),RAD(24,65),ANG(24,65),XK(24,65),YK(24,65),  AMZ2860
     2NU(6),MU(6),NK(10),MK(10),AH(7,10),CAPAP(7,10),PREC(7,10),ARG(7,10 AMZ2870
     3),PERU(5),PERV(5),NL(5),ML(5),NZ(20),MZ(20),V1(20),UPB(24,65),      AMZ2880
     4VPB(24,65),S(24,65),A(3),V2(20),V3(20),V4(20),HGU(24,65),HGV(24,65 AMZ2890
     5),H(7),B(7),AL(7),CAPA(7),CAPB(7),AINC(7),CAINC(7),NG(5),MG(5),     AMZ2900
     6TIT(4),AUS(4),TAR(4),OTC(4)                                        AMZ2910
      DIMENSION MAP(24,65),TITLE(8),UPLOT(24,65),VPLOT(24,65)            AMZ2920
COMPUTATIONS                                                             AMZ2930
TIDAL INPUT                                                              AMZ2940
THE TIDES ARE THOSE OF 'LIMAO DO CURUA' AND SEVEN COMPONENTS ARE         AMZ2950
USED, THE INPUT WAS DONE AT THE SECOND COLUMN OF THE COMPUTATIONAL       AMZ2960
GRID, AT M EQUALS TWO                                                    AMZ2970
  309 CONTINUE                                                           AMZ2980
  310 DO 328 I=1,7                                                       AMZ2990
  311 DO 328 J=1,KO                                                      AMZ3000
  312 PREC(I,J)=AL(I)*T-CAPAP(I,J)                                       AMZ3010
  313 IF(PREC(I,J))314,321,315                                           AMZ3020
  315 IF(PREC(I,J)-6.283185)318,318,316                                  AMZ3030
  314 PREC(I,J)=6.283185+PREC(I,J)                                       AMZ3040
  316 PREC(I,J)=PREC(I,J)-6.283185                                       AMZ3050
  317 GO TO 315                                                          AMZ3060
  318 IF(PREC(I,J)-1.570796)321,321,319                                  AMZ3070
  319 IF(PREC(I,J)-3.141593) 323,323,320                                 AMZ3080
  320 IF(PREC(I,J)-4.712389)325,325,327                                  AMZ3090
  321 ARG(I,J)=COS (PREC(I,J))                                           AMZ3100
  322 GO TO 328                                                          AMZ3110
  323 ARG(I,J)=-COS (3.141593-PREC(I,J))                                 AMZ3120
  324 GO TO 328                                                          AMZ3130
  325 ARG(I,J)=-COS (PREC(I,J)-3.141593)                                 AMZ3140
  326 GO TO 328                                                          AMZ3150
  327 ARG(I,J)=COS (6.283185-PREC(I,J))                                  AMZ3160
  328 CONTINUE                                                           AMZ3170
  380 DO 384 I=1,KO                                                      AMZ3180
  381 N=NK(I)                                                            AMZ3190
  382 M=MK(I)                                                            AMZ3200
  383 Z(N,M)=AH(1,I)*ARG(1,I)+AH(2,I)*ARG(2,I)+AH(3,I)*ARG(3,I)+AH(4,I)* AMZ3210
     1 ARG(4,I)+AH(5,I)*ARG(5,I)+AH(6,I)*ARG(6,I)+AH(7,I)*ARG(7,I)       AMZ3220
  384 CONTINUE                                                           AMZ3230
 COMPUTATION OF Z-BAR                                                    AMZ3240
  390 DO 394 N=1,NE                                                      AMZ3250
  391 DO 394 M=1,ME                                                      AMZ3260
  392 UPB(N,M)=0.                                                        AMZ3270
  393 VPB(N,M)=0.                                                        AMZ3280
  394 CONTINUE                                                           AMZ3290
  500 DO 523 N=1,NE                                                      AMZ3300
  501 DO 523 M=1,ME                                                      AMZ3310
  502 IF(HTZ(N,M))523,523,503                                            AMZ3320
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  503 IF(1-N)504,507,504                                                                                                AMZ3330
  504 IF(HTZ(N-1,M))505,507,505                                                                                         AMZ3340
  505 VAUP=Z(N-1,M)                                                                                                     AMZ3350
  506 GO TO 508                                                                                                         AMZ3360
  507 VAUP=Z(N,M)                                                                                                       AMZ3370
  508 IF(NE-N)509,512,509                                                                                               AMZ3380
  509 IF(HTZ(N+1,M))510,512,510                                                                                         AMZ3390
  510 VALO=Z(N+1,M)                                                                                                     AMZ3400
  511 GO TO 513                                                                                                         AMZ3410
  512 VALO=Z(N,M)                                                                                                       AMZ3420
  513 IF(1-M)514,516,514                                                                                                AMZ3430
  514 IF(HTZ(N,M-1))1514,516,1514                                                                                       AMZ3440
 1514 VALE=Z(N,M-1)                                                                                                     AMZ3450
  515 GO TO 517                                                                                                         AMZ3460
  516 VALE=Z(N,M)                                                                                                       AMZ3470
  517 IF(ME-M)518,521,518                                                                                               AMZ3480
  518 IF(HTZ(N,M+1))519,521,519                                                                                         AMZ3490
  519 VARI=Z(N,M+1)                                                                                                     AMZ3500
  520 GO TO 522                                                                                                         AMZ3510
  521 VARI=Z(N,M)                                                                                                       AMZ3520
  522 VPB(N,M)=ALPHA*Z(N,M)+BETA*(VAUP+VALO+VALE+VARI)                                                                  AMZ3530
  523 CONTINUE                                                                                                          AMZ3540
COMPUTATION OF Z                                                                                                        AMZ3550
  530 DO 535 N=2,NEH                                                                                                    AMZ3560
  531 DO 535 M=3,ME                                                                                                     AMZ3570
  532 IF(HTZ(N,M)) 535,535,2533                                                                                         AMZ3580
 2533 IF(HTZ(N,M)-3.)535,535,533                                                                                        AMZ3590
  533 Z(N,M)=VPB(N,M)-A4*(HGU(N,M)*U(N,M)-HGU(N,M-1)*U(N,M-1)+HGV(N-1,M)                                                AMZ3600
     1*V(N-1,M)-HGV(N,M)*V(N,M))                                                                                        AMZ3610
  535 CONTINUE                                                                                                          AMZ3620
COMPUTATION OF REAL DEPTHS                                                                                              AMZ3630
 1537 DO 1543 N = 1,NEH                                                                                                 AMZ3640
 1538 DO 1543 M = 1,MEH                                                                                                 AMZ3650
 1539 IF(HTU(N,M)) 1541,1541,1540                                                                                       AMZ3660
 1540 HGU(N,M) = HTU(N,M) +(Z(N,M)+Z(N,M+1))/2.                                                                         AMZ3670
 1541 IF(HTV(N,M)) 1543,1543,1542                                                                                       AMZ3680
 1542 HGV(N,M) = HTV(N,M)+(Z(N,M)+Z(N+1,M))/2.                                                                          AMZ3690
 1543 CONTINUE                                                                                                          AMZ3700
CHECKING OF 'DRYING'  OF TIDAL FLATS                                                                                    AMZ3710
 1560 DO 1568 N=1,NE                                                                                                    AMZ3720
 1561 DO 1568 M=1,ME                                                                                                    AMZ3730
 1562 IF(HTU(N,M))1565,1565,1563                                                                                        AMZ3740
 1563 IF(HGU(N,M)-10.)1564,1564,1565                                                                                    AMZ3750
 1564 HGU(N,M)=-3.                                                                                                      AMZ3760
 1565 IF(HTV(N,M))1568,1568,1566                                                                                        AMZ3770
 1566 IF(HGV(N,M)-10.)1567,1567,1568                                                                                    AMZ3780
 1567 HGV(N,M)=-3.                                                                                                      AMZ3790
 1568 CONTINUE                                                                                                          AMZ3800
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C COMPUTATION OF U-BAR                                                  AMZ3810
  540 DO 585 N=2,NEH                                                    AMZ3820
  541 DO 585 M=2,MEH                                                    AMZ3830
  542 IF(HTU(N,M))585,585,543                                           AMZ3840
  543 IF(1-N)544,547,544                                                AMZ3850
  544 IF(HTU(N-1,M))545,547,545                                         AMZ3860
  545 VUP=U(N-1,M)                                                      AMZ3870
  546 GO TO 548                                                         AMZ3880
  547 VUP=U(N,M)                                                        AMZ3890
  548 IF(NE-N)549,552,549                                               AMZ3900
  549 IF(HTU(N+1,M))550,552,550                                         AMZ3910
  550 VLO=U(N+1,M)                                                      AMZ3920
  551 GO TO 553                                                         AMZ3930
  552 VLO=U(N,M)                                                        AMZ3940
  553 IF(1-M)554,557,554                                                AMZ3950
  554 IF(HTU(N,M-1))555,557,555                                         AMZ3960
  555 VLE=U(N,M-1)                                                      AMZ3970
  556 GO TO 558                                                         AMZ3980
  557 VLE=U(N,M)                                                        AMZ3990
  558 IF(ME-M)559,562,559                                               AMZ4000
  559 IF(HTU(N,M+1))560,562,560                                         AMZ4010
  560 VRI=U(N,M+1)                                                      AMZ4020
  561 GO TO 563                                                         AMZ4030
  562 VRI=U(N,M)                                                        AMZ4040
  563 UPB(N,M)=ALPHA*U(N,M)+BETA*(VUP+VLO+VLE+VRI)                      AMZ4050
C COMPUTATION OF V-STAR                                                 AMZ4060
  564 IF(HTV(N-1,M))565,569,565                                         AMZ4070
  565 VUL=V(N-1,M)                                                      AMZ4080
  566 IF(HTV(N-1,M+1))567,570,567                                       AMZ4090
  567 VUR=V(N-1,M+1)                                                    AMZ4100
  568 GO TO 571                                                         AMZ4110
  569 VUL=V(N-1,M+1)                                                    AMZ4120
  570 VUR=VUL                                                           AMZ4130
  571 IF(HTV(N,M))572,576,572                                           AMZ4140
  572 VLL=V(N,M)                                                        AMZ4150
  573 IF(HTV(N,M+1))574,577,574                                         AMZ4160
  574 VLR=V(N,M+1)                                                      AMZ4170
  575 GO TO 578                                                         AMZ4180
  576 VLL=V(N,M+1)                                                      AMZ4190
  577 VLR=VLL                                                           AMZ4200
  578 VPB(N,M)=(VUL+VLL+VUR+VLR)/4.                                     AMZ4210
  585 CONTINUE                                                          AMZ4220
C COMPUTATION OF U                                                      AMZ4230
  586 DO 595 N=2,NEH                                                    AMZ4240
  587 DO 595 M=2,MEH                                                    AMZ4250
  588 IF(HTU(N,M)) 595,595,1570                                         AMZ4260
 1570 IF(HGU(N,M)-3.) 595,1571,589                                      AMZ4270
 1571 VPB(N,M)=0.                                                       AMZ4280
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 1572 GO TO 595                                                                  AMZ4290
  589 IF(UPB(N,M)*UPB(N,M))595,590,591                                           AMZ4300
  590 IF(VPB(N,M)*VPB(N,M))595,595,591                                           AMZ4310
  591 ROOT=SQRT (UPB(N,M)*UPB(N,M)+VPB(N,M)*VPB(N,M))                            AMZ4320
  592 GRZ=A3*ROOT                                                               AMZ4330
  593 VPB(N,M)= (1. - GRZ/HGU(N,M))*UPB(N,M) + A2*VPB(N,M) - A5*                 AMZ4340
     1(Z(N,M+1) - Z(N,M)) + XK(N,M)                                             AMZ4350
  595 CONTINUE                                                                   AMZ4360
                                                                                 AMZ4370
SPECIAL INFLOW SETTING                                                           AMZ4380
U-COMPONENT OF SPECIAL INFLOW SETTING                                            AMZ4390
THE RIVER INFLOW WAS INTRODUCED AT THE SECTION PERPENDICULAR TO                  AMZ4400
MACAPA                                                                           AMZ4410
 1590 IF(LU)900,900,1591                                                         AMZ4420
 1591 DO 1595 I=1,LU                                                             AMZ4430
 1592 N=NL(I)                                                                    AMZ4440
 1593 M=ML(I)                                                                    AMZ4450
 1594 VPB(N,M) = PERU(I) + VPB(N,M)                                              AMZ4460
 1595 CONTINUE                                                                   AMZ4470
 3596 DO 3600 N=1,NE                                                             AMZ4480
      IF(HTU(N,1))3600,3600,3597                                                 AMZ4490
 3597 IF(HTU(N,2))3600,3600,3598                                                 AMZ4500
 3598 VPB(N,1)=VPB(N,2)*HTU(N,1)/HTU(N,2)                                        AMZ4510
 3600 CONTINUE                                                                   AMZ4520
COMPUTATION OF U-STAR                                                            AMZ4530
  900 DO 918 N=1,NEH                                                             AMZ4540
  901 DO 918 M = 2,ME                                                            AMZ4550
  902 IF(HTV(N,M))918,918,903                                                    AMZ4560
  903 IF(HTU(N,M-1))904,908,904                                                  AMZ4570
  904 VUL=U(N,M-1)                                                               AMZ4580
  905 IF(HTU(N+1,M-1))906,909,906                                                AMZ4590
  906 VLL=U(N+1,M-1)                                                             AMZ4600
  907 GO TO 910                                                                  AMZ4610
  908 VUL=U(N+1,M-1)                                                             AMZ4620
  909 VLL=VUL                                                                    AMZ4630
  910 IF(HTU(N,M))911,915,911                                                    AMZ4640
  911 VUR=U(N,M)                                                                 AMZ4650
  912 IF(HTU(N+1,M))913,916,913                                                  AMZ4660
  913 VLR=U(N+1,M)                                                               AMZ4670
  914 GO TO 917                                                                  AMZ4680
  915 VUR=U(N+1,M)                                                               AMZ4690
  916 VLR=VUR                                                                    AMZ4700
  917 UPB(N,M)=(VUL+VLL+VUR+VLR)/4.                                              AMZ4710
  918 CONTINUE                                                                   AMZ4720
TRANSFER OF NEW U INTO PROPER ARRAY                                              AMZ4730
      GO TO 920                                                                  AMZ4740
  920 DO 924 N=1,NE                                                              AMZ4750
  921 DO 924 M=1,ME                                                              AMZ4760
  922 IF(HTU(N,M))924,924,923                                                    AMZ4770
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  923 U(N,M) = VPB(N,M)                                                          AMZ4770
  924 CONTINUE                                                                   AMZ4780
COMPUTATION OF V-BAR                                                             AMZ4790
  930 DO 954 N=1,NE                                                              AMZ4800
  931 DO 954 M=1,ME                                                              AMZ4810
  932 IF(HTV(N,M))954,954,933                                                    AMZ4820
  933 IF(1-N)934,937,934                                                         AMZ4830
  934 IF(HTV(N-1,M))935,937,935                                                  AMZ4840
  935 VUP=V(N-1,M)                                                               AMZ4850
  936 GO TO 938                                                                  AMZ4860
  937 VUP=V(N,M)                                                                 AMZ4870
  938 IF(NE-N)939,942,939                                                        AMZ4880
  939 IF(HTV(N+1,M))940,942,940                                                  AMZ4890
  940 VLO=V(N+1,M)                                                               AMZ4900
  941 GO TO 943                                                                  AMZ4910
  942 VLO=V(N,M)                                                                 AMZ4920
  943 IF(1-M)944,947,944                                                         AMZ4930
  944 IF(HTV(N,M+1))945,947,945                                                  AMZ4940
  945 VLE=V(N,M-1)                                                               AMZ4950
  946 GO TO 948                                                                  AMZ4960
  947 VLE=V(N,M)                                                                 AMZ4970
  948 IF(ME-M)949.952,949                                                        AMZ4980
  949 IF(HTV(N,M+1))950,952,950                                                  AMZ4990
  950 VRI=V(N,M+1)                                                               AMZ5000
  951 GO TO 953                                                                  AMZ5010
  952 VRI=V(N,M)                                                                 AMZ5020
  953 VPB(N,M)=ALPHA*V(N,M)+BETA*(VUP+VLO+VLE+VRI)                               AMZ5030
  954 CONTINUE                                                                   AMZ5040
COMPUTATION OF V                                                                 AMZ5050
  960 DO 969 N = 2,NEH                                                           AMZ5060
  961 DO 969 M=1,MEH                                                             AMZ5070
  962 IF(HTV(N,M)) 969,969,1990                                                  AMZ5080
 1990 IF(HGV(N,M)-3.) 969,1991,963                                               AMZ5090
 1991 V(N,M)=0.                                                                  AMZ5100
 1992 GO TO 969                                                                  AMZ5110
  963 IF(VPB(N,M)*VPB(N,M))969,964,965                                           AMZ5120
  964 IF(UPB(N,M)*UPB(N,M))969,969,965                                           AMZ5130
  965 ROOT=SQRT (VPB(N,M)*VPB(N,M)+UPB(N,M)*UPB(N,M))                            AMZ5140
  966 GRZ=A3*ROOT                                                                AMZ5150
  967 V (N,M) = (1. - GRZ/HGV(N,M))*VPB(N,M) - A2*UPB(N,M) - A5*(Z(N,M)          AMZ5160
     1 - Z(N+1,M)) + YK(N,M)                                                     AMZ5170
  969 CONTINUE                                                                   AMZ5180
V-COMPONENT OF SPECIAL INFLOW SETTING                                            AMZ5190
      DO 6000 I=1,4                                                              AMZ5200
      N=NL(I)                                                                    AMZ5210
      M=ML(I)                                                                    AMZ5220
      V(N,M)= PERV(I) + V(N,M)                                                   AMZ5230
 6000 CONTINUE                                                                   AMZ5240
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  300 CONTINUE                                                          AMZ5250
  472 CONTINUE                                                          AMZ5260
      RETURN                                                            AMZ5270
      END                                                               AMZ5280
      SUBROUTINE JOB3                                                   AMZ5290
      COMMON HTZ,HTU,HTV,Z,U,V,US,VS,RAD,ANG,XK,YK,NU,MU,NK,MK,AH,CAPAP,  AMZ5300
     1PREC,ARG,PERU,PERV,NL,ML,NZ,MZ,V1,UPB,VPB,S,A,V2,V3 V4,HGU,HGV,H,  AMZ5310
     2B,AL,CAPA,CAPB,AINC,CAINC,NG,MG,TIT,AUS,TAR,OTC,T1,T2,T4,TE,TW,A1,  AMZ5320
     3A2,A3,A4,DT,BETA,ALPHA,F,R,DL,G,C,C3,NE,ME,NEH,MEH,JA,IUE,KKE,NURU  AMZ5330
     4,SI,T,RBETA,C1,SIGMA,ROL,A5,RU,RV,KO,LI,LE,LU,KI,LOP,TRB,TRE,TIC,   AMZ5340
     5LUN,LA,TIL,LIV,LEET,POSN,POSM,DRI,STV,ETV,TINCV,STH,ETC,TINCH,CNCU  AMZ5350
     6,CAINCU                                                           AMZ5360
      DIMENSION HTZ(24,65),HTU(24,65),HTV(24,65),Z(24,65),U(24,65),V(24,  AMZ5370
     165),US(24,65),VS(24,65),RAD(24,65),ANG(24,65),XK(24,65),YK(24,65),  AMZ5380
     2NU(6),MU(6),NK(10),MK(10),AH(7,10),CAPAP(7,10),PREC(7,10),ARG(7,10  AMZ5390
     3),PERU(5),PERV(5),NL(5),ML(5),NZ(20),MZ(20),V1(20),UPB(24,65),      AMZ5400
     4VPB(24,65),S(24,65),A(3),V2(20),V3(20),V4(20),HGU(24,65),HGV(24,65  AMZ5410
     5),H(7),B(7),AL(7),CAPA(7),CAPB(7),AINC(7),CAINC(7),NG(5),MG(5),     AMZ5420
     6TIT(4),AUS(4),TAR(4),OTC(4)                                       AMZ5430
      DIMENSION MAP(24,65),TITLE(8),UPLOT(24,65),VPLOT(24,65)           AMZ5440
WRITING OF OUTPUT FIELDS                                                AMZ5450
 1605 FORMAT(//8X,5I8)                                                  AMZ5460
 1604 FORMAT(I8,5F8.0,/)                                                AMZ5470
   32 FORMAT(9F8.0)                                                     AMZ5480
  601 CONTINUE                                                          AMZ5490
  610 PRINT602,T,(N,N=1,15)                                             AMZ5500
  611 PRINT604,(N,(Z(N,M),M=1,15),N=1,NE)                               AMZ5510
  612 PRINT605,(N,N=16,30)                                              AMZ5520
  613 PRINT604,(N,(Z(N,M),M=16,30),N=1,NE)                              AMZ5530
      PRINT605,(N,N=31,45)                                              AMZ5540
      PRINT604,(N,(Z(N,M),M=31,45),N=1,NE)                              AMZ5550
      PRINT605,(N,N=46,60)                                              AMZ5560
      PRINT604,(N,(Z(N,M),M=46,60),N=1,NE)                              AMZ5570
      PRINT 1605,(N,N=61,65)                                            AMZ5580
      PRINT 1604,(N,(Z(N,M),M=61,65),N=1,NE)                            AMZ5590
COMPUTATION OF SPEED AND DIRECTION FROM U AND V COMPONENTS              AMZ5600
  614 DO 639 N=1,NE                                                     AMZ5610
  617 DO 639 M=1,ME                                                     AMZ5620
  618 IF(V(N,M))620,619,620                                             AMZ5630
  619 IF(U(N,M))620,622,620                                             AMZ5640
  620 RAD(N,M)=SQRT (ABS (V(N,M))**2+ABS (U(N,M))**2)                   AMZ5650
  621 GO TO 625                                                         AMZ5660
  622 RAD(N,M)=0.                                                       AMZ5670
  623 ANG(N,M)=0.                                                       AMZ5680
  624 GO TO 639                                                         AMZ5690
  625 ANG(N,M)=ABS (ARSIN(V(N,M)/RAD(N,M)))                             AMZ5700
  626 ANG(N,M)=ANG(N,M)*(360./6.2831853073)                             AMZ5710
  627 IF(V(N,M))629,628,628                                             AMZ5720
```

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  628 IF(U(N,M))631,636,636                                                    AMZ5730
  629 IF(U(N,M))633,633,630                                                    AMZ5740
  630 GO TO 635                                                                AMZ5750
  631 ANG(N,M)=180.-ANG(N,M)                                                   AMZ5760
  632 GO TO 636                                                                AMZ5770
  633 ANG(N,M)=180.+ANG(N,M)                                                   AMZ5780
  634 GO TO 636                                                                AMZ5790
  635 ANG(N,M)=360.-ANG(N,M)                                                   AMZ5800
  636 ANG(N,M) = (90.-ANG(N,M)) - TIL                                          AMZ5810
  637 IF(ANG(N,M))638,639,639                                                  AMZ5820
  638 ANG(N,M)=360.+ANG(N,M)                                                   AMZ5830
 2638 GO TO 637                                                                AMZ5840
  639 CONTINUE                                                                 AMZ5850
      IF(T.LT.230400.)GO TO 2000                                               AMZ5860
PREPARATION OF CURRENT COMPONENTS TO BE PLOTTED IN GRID                        AMZ5870
      DO 6000 N=1,NE                                                           AMZ5880
      DO 6000 M=1,ME                                                           AMZ5890
      UPLOT(N,M) = RAD(N,M) * SIN((ANG(N,M)+208.)*0.0174533)                   AMZ5900
 6000 VPLOT(N,M) = -RAD(N,M) * COS((ANG(N,M)+208.)*0.0174533)                  AMZ5910
      READ(5,500) TITLE                                                        AMZ5920
  500 FORMAT (8A4)                                                             AMZ5930
      CALL STREAM(24,65,VPLOT,UPLOT,MAP,1.0,1.0,4,.51,TITLE,3.00,3.00,         AMZ5940
     12,1,400.)                                                                AMZ5950
 2000 CONTINUE                                                                 AMZ5960
PRINTING OF OUTPUT FIELDS                                                      AMZ5970
  650 PRINT 607,T,(N,N=1,10)                                                   AMZ5980
  651 PRINT 606,(N,(RAD(N,M),ANG(N,M),M=1,10),N=1,NE)                          AMZ5990
  652 PRINT 609,(N,N=11,20)                                                    AMZ6000
  653 PRINT 608,(N,(RAD(N,M),ANG(N,M),M=11,20),N=1,NE)                         AMZ6010
      PRINT 609,(N,N=21,30)                                                    AMZ6020
      PRINT 608,(N,(RAD(N,M),ANG(N,M),M=21,30),N=1,NE)                         AMZ6030
      PRINT 609,(N,N=31,40)                                                    AMZ6040
      PRINT 608,(N,(RAD(N,M),ANG(N,M),M=31,40),N=1,NE)                         AMZ6050
      PRINT 609,(N,N=41,50)                                                    AMZ6060
      PRINT 608,(N,(RAD(N,M),ANG(N,M),M=41,50),N=1,NE)                         AMZ6070
      PRINT 609,(N,N=51,60)                                                    AMZ6080
      PRINT 608,(N,(RAD(N,M),ANG(N,M),M=51,60),N=1,NE)                         AMZ6090
      PRINT 1609,(N,N=61,65)                                                   AMZ6100
      PRINT 1608,(N,(RAD(N,M),ANG(N,M),M=61,65),N=1,NE)                        AMZ6110
  660 IF(LI) 1630,1630,661                                                     AMZ6120
  661 PRINT 670,T,(N,N=1,15)                                                   AMZ6130
  662 PRINT 604,(N,(S(N,M),M=1,15),N=1,NE)                                     AMZ6140
      PRINT 605,(N,N=16,30)                                                    AMZ6150
      PRINT 604,(N,(S(N,M),M=16,30),N=1,NE)                                    AMZ6160
      PRINT 605,(N,N=31,45)                                                    AMZ6170
      PRINT 604,(N,(S(N,M),M=31,45),N=1,NE)                                    AMZ6180
      PRINT 605,(N,N=46,60)                                                    AMZ6190
      PRINT 604,(N,(S(N,M),M=46,60),N=1,NE)                                    AMZ6200
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      PRINT 1605,(N,N=61,65)                                                    AMZ6210
      PRINT 1604,(N,(S(N,M),M=61,65),N=1,NE)                                    AMZ6220
  670 FORMAT(1H1,14X,22HCONCENTRATION AFTER T=,F9.0,//8X,I8,15I8//)             AMZ6230
 1609 FORMAT(//8X,I7,6I8)                                                       AMZ6240
WRITING OF DATA FROM SELECTED POINTS ON TAPE                                    AMZ6250
 1638 LOP=LOP+10                                                                AMZ6260
 1639 GO TO 614                                                                 AMZ6270
 1630 CONTINUE                                                                  AMZ6280
  640 DO 646 I=1,NURU                                                           AMZ6290
  641 N=NZ(I)                                                                   AMZ6300
  642 M=MZ(I)                                                                   AMZ6310
  643 V2(I)=Z(N,M)                                                              AMZ6320
  644 V3(I)=RAD(N,M)                                                            AMZ6330
  645 V4(I)=ANG(N,M)                                                            AMZ6340
  646 CONTINUE                                                                  AMZ6350
  647 WRITE(12) T,(V2(I),I=1,NURU)                                              AMZ6360
      WRITE(12) T,(V3(I),I=1,NURU)                                              AMZ6370
      WRITE(12) T,(V4(I),I=1,NURU)                                              AMZ6380
  602 FORMAT(1H1,14X,21HWATER HEIGHT AFTER T=,F9.0,9H SEC (CM)//8X,15I8/        AMZ6390
     1/)                                                                        AMZ6400
  604 FORMAT(I8,15F8.0/)                                                        AMZ6410
  605 FORMAT(//8X,15I8/)                                                        AMZ6420
  607 FORMAT(1H1,14X,76HRESULTANT CURRENT VELOCITY MAGNITUDE(CM/SEC) AND        AMZ6430
     1DIRECTION(DEGREES) AFTER T= ,F9.0,4H SEC,//8X,10I9)                       AMZ6440
  606 FORMAT((I8,10(F4.0,1H,,F4.0)/))                                           AMZ6450
  608 FORMAT((I8,10(F4.0,1H,,F4.0)/))                                           AMZ6460
 1608 FORMAT((I8, 5(F4.0,1H,,F4.0)/))                                           AMZ6470
  609 FORMAT(8X,I7,9I9/)                                                        AMZ6480
 1670 FORMAT(///,5X,31HPOSITION OF DRIFTING OBJECT, N=,F6.2,2HM=,F6.2,//        AMZ6490
     1/)                                                                        AMZ6500
  654 CONTINUE                                                                  AMZ6510
 3620 CONTINUE                                                                  AMZ6520
      RETURN                                                                    AMZ6530
      END                                                                       AMZ6540
      SUBROUTINE JOB5                                                           AMZ6550
      COMMON HTZ,HTU,HTV,Z,U,V,US,VS,RAD,ANG,XK,YK,NU,MU,NK,MK,AH,CAPAP,        AMZ6560
     1PREC,ARG,PERU,PERV,NL,ML,NZ,MZ,V1,UPB,VPB,S,A,V2,V3,V4,HGU,HGV,H,        AMZ6570
     2B,AL,CAPA,CAPB,AINC,CAINC,NG,MG,TIT,AUS,TAR,DTC,T1,T2,T4,TE,TW,AI,       AMZ6580
     3A2,A3,A4,DT,BETA,ALPHA,F,R,DL,G,C,C3,NE,ME,NEH,MEH,JA,IUE,KKE,NURU       AMZ6590
     4,SI,T,RBETA,C1,SIGMA,ROL,A5,RU,RV,KO,LI,LE,LU,KI,LOP,TRB,TRE,TIC,        AMZ6600
     5LUN,LA,TIL,LIV,LEET,POSN,POSM,DRI,STV,ETV,TINCV,STH,ETC,TINCH,CNCU       AMZ6610
     6,CAINCU                                                                   AMZ6620
      DIMENSION HTZ(24,65),HTU(24,65),HTV(24,65),Z(24,65),U(24,65),V(24,        AMZ6630
     165),US(24,65),VS(24,65),RAD(24,65),ANG(24,65),XK(24,65),YK(24,65),        AMZ6640
     2NU(6),MU(6),NK(10),MK(10),AH(7,10),CAPAP(7,10),PREC(7,10),ARG(7,10       AMZ6650
     3),PERU(5),PERV(5),NL(5),ML(5),NZ(20),MZ(20),V1(20),UPB(24,65),            AMZ6660
     4VPB(24,65),S(24,65),A(3),V2(20),V3(20),V4(20),HGU(24,65),HGV(24,65        AMZ6670
     5),H(7),B(7),AL(7),CAPA(7),CAPB(7),AINC(7),CAINC(7),NG(5),MG(5),           AMZ6680
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     6TIT(4),AUS(4),TAR(4),OTC(4)                                                    AMZ6690
      DIMENSION MAP(24,65),TITLE(8),UPLOT(24,65),VPLOT(24,65)                        AMZ6700
OUTPUT OF SPECIAL POINTS                                                             AMZ6710
      REWIND 12                                                                      AMZ6720
  802 CONTINUE                                                                       AMZ6730
  803 FORMAT(1H1,5X,114HWATER ELEVATION(CM) AND CURRENT VELOCITY RESULTA             AMZ6740
     1NT(MAGNITUDE IN CM(SEC AND DIRECTION IN DEGREES) AT SPECIAL POINTS             AMZ6750
     2///7X,4HTIME,4X,12(4X,A5)/15X,5(4X,A5)/)                                       AMZ6760
  804 FORMAT(6X,5H(SEC),4X,12(2X,I3,1H,,I3)/15X,5(2X,I3,1H,,I3)//)                   AMZ6770
OUTPUT AT SPECIAL POINTS                                                             AMZ6780
  805 FORMAT(F11.0,4X,12F9.2/15X,5F9.2)                                              AMZ6790
  806 FORMAT(5X,14HEND OF PROGRAM)                                                   AMZ6800
  807 FORMAT(15X,12(F4.0,1H,,F4.0)/15X,5(F4.0,1H,,F4.0)/)                            AMZ6810
  808 PRINT 803,(V1(I),I=1,NURU)                                                     AMZ6820
  809 PRINT 804,(NZ(I),MZ(I),I=1,NURU)                                               AMZ6830
  810 READ(12)  T,(V2(I),I=1,NURU)                                                   AMZ6840
      READ(12)  T,(V3(I),I=1,NURU)                                                   AMZ6850
      READ(12)  T,(V4(I),I=1,NURU)                                                   AMZ6860
  813 PRINT 805,T,(V2(I),I=1,NURU)                                                   AMZ6870
  814 PRINT 807,(V3(I),V4(I),I=1,NURU)                                               AMZ6880
  815 IF (TE-T)816,816,810                                                           AMZ6890
  816 PRINT 806                                                                      AMZ6900
      RETURN                                                                         AMZ6910
      END                                                                            AMZ6920
```

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